FOR THE HOMEBREWER AND BEER LOVER

Zymurgy

Vol. 12, No. 4
Special 1989

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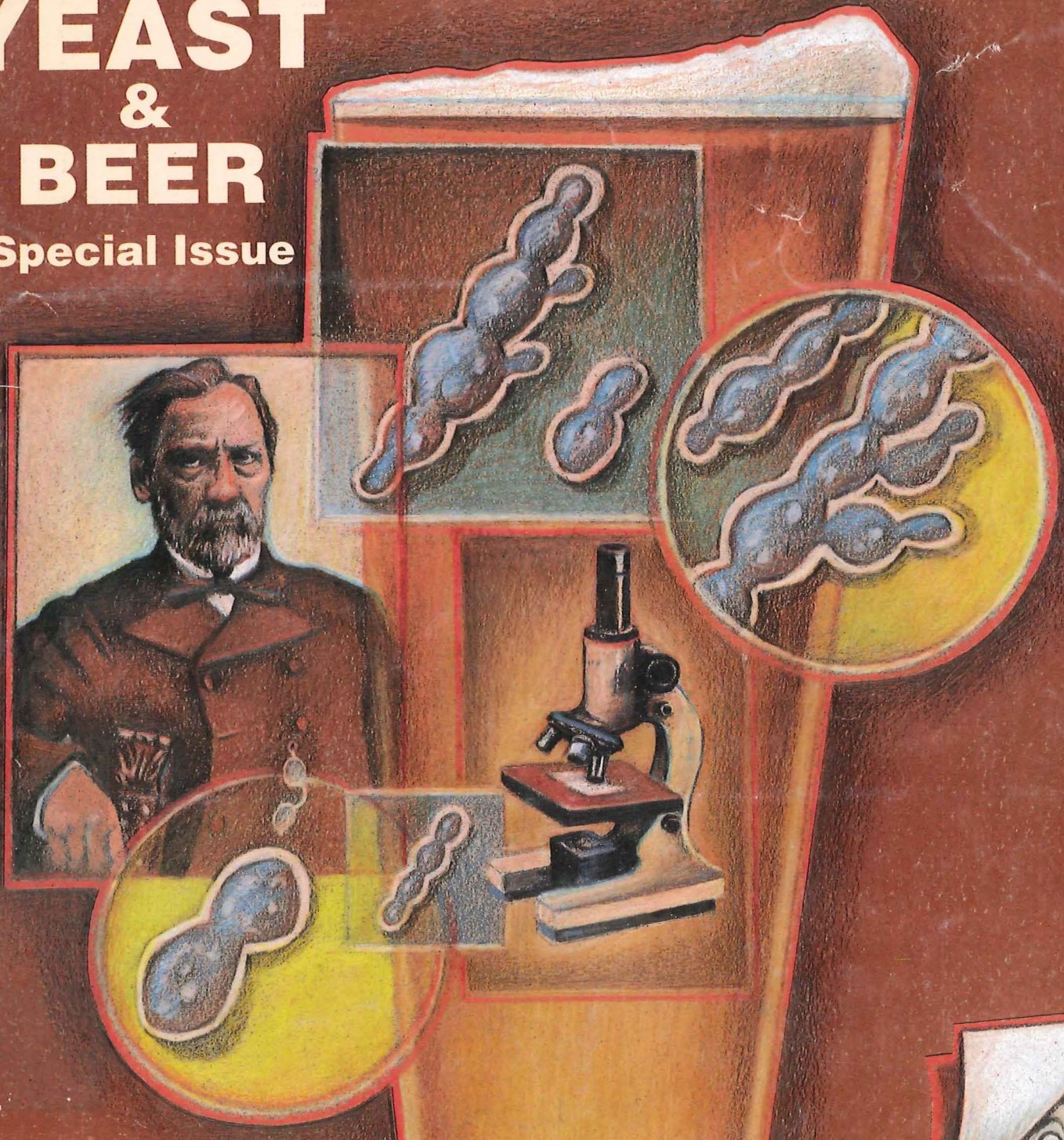
$8.50

YEAST & BEER

Special Issue



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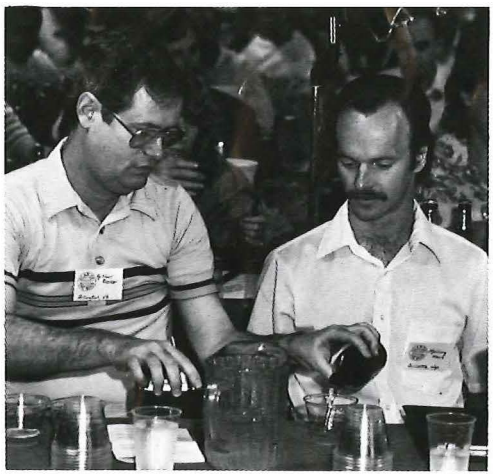

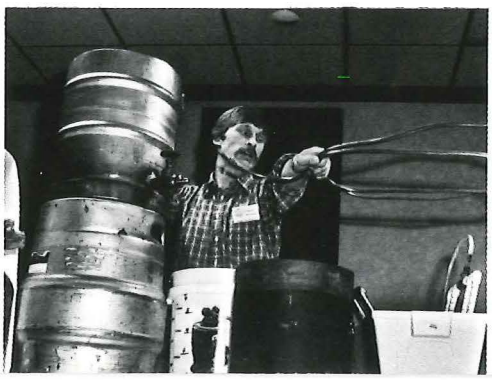

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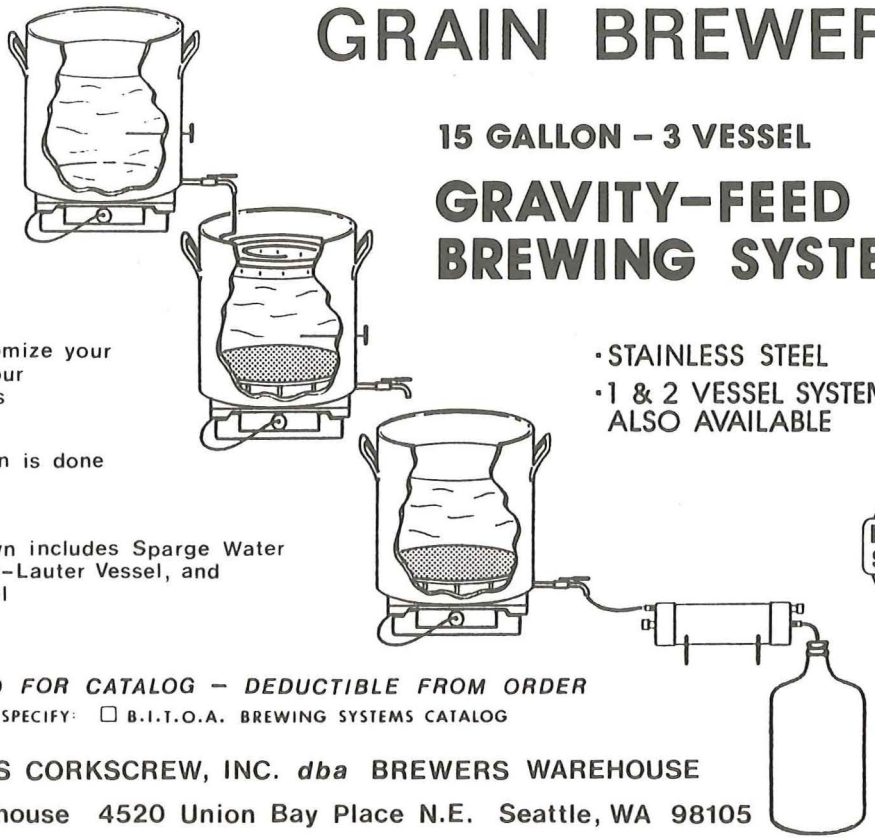

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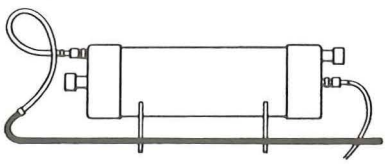

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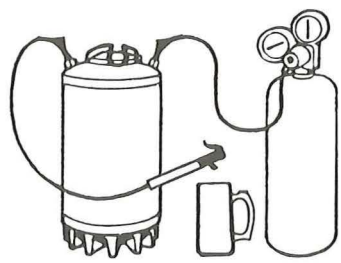

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Zymurgy

Volume 12, Number 4

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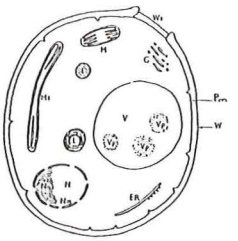

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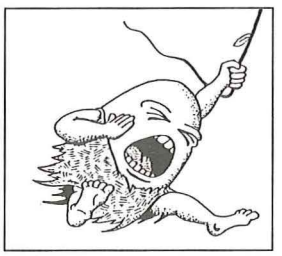

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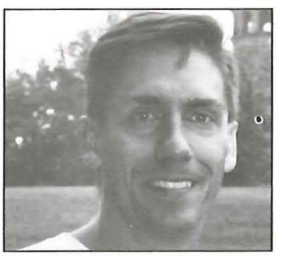

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Paul Prozeller, Homebrewer of the Year

Cover art by Monica Morabito

Animated yeast illustrations throughout by Martin Hess

Zymurgy

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zymurgy welcomes letters, opinions, ideas, stories and information in general from its readers. Correspondence and advertising inquiries should be directed to ***zymurgy***, Box 287, Boulder, CO 80306-0287, (303)447-0816.

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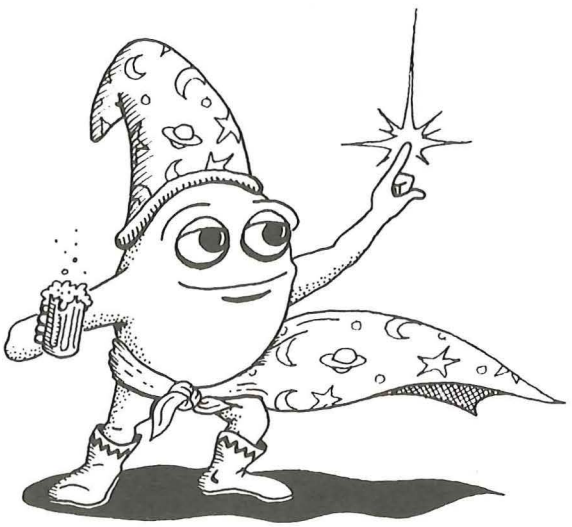
THE AMERICAN HOMEBREWERS ASSOCIATION MISSION STATEMENT

To help maintain quality in the production and distribution of beer; to promote public awareness and appreciation of the quality and variety of beer through education, research and the collection and dissemination of information; to serve as a forum for the technological and cross-cultural aspects of the art of brewing; and to encourage responsible use of beer as an alcohol-containing beverage.

INTRODUCTION

CHARLIE PAPAZIAN

YEAST



The Sorcerer's Apprentice

How many millions of packages of dried yeast have been torn open and unceremoniously added like some chemical ingredient to a freshly brewed batch of homebrew? I wonder. If you began your interest in homebrewing as I did, you probably never gave that dried, cream-colored "stuff" much consideration. Yeast was yeast and it helped turn sweet wort into beer.

After a glass or two of my first efforts, I believed in magic and it was only later that I began to wonder how that dried powder really did what it did: Make my beer.

When I was brewing my first batches of beer, years ago, virtually no real information about yeast was accessible to homebrewers. For years I was left simply to sit in a comfortable chair, wondering about the magic of yeast, the bubbles and the alcohol. With my senses I learned how it behaved, but I didn't know why.

In those early days of homebrewing I enjoyed my beer and my naiveté. And to tell you the truth, I wouldn't deny that experience to any beginner. It is a feeling that brewers have enjoyed for over 5,000 years. One cannot help but feel like a sorcerer while mixing, boiling, fermenting and aging in all the appropriate proportions and then making that magnificent and ceremonial presentation of an elixir that stirs the mind, safely quenches the thirst and appeases the gods. Poems, songs, castles and entire cities have had their origins in the mysteries of fermentation.

As beginners, it is comforting that despite our naiveté about the science of yeast and fermentation, we can still enjoy the pleasures and the fantasies of being brewers. We are linked to all brewers since the ancient Sumerians and Egyptians first discovered the powers of beer and brewing.

Yeast, a living fungal micro-organism whose life processes convert sweet wort into beer, was not known per se until the middle of the 19th century. The famous Bavarian purity law of 1516 makes no mention of yeast, only that beer should be made with water, malt and hops. It wasn't until the pioneering work of the Frenchman, Louis Pasteur, in the mid-1800s that pure strains of yeast were isolated and cultured and the workings of yeast and fermentation were explained.

I have learned slowly over the years about yeast and fermentation. I am not a chemist, nor am I a microbiologist. I am a brewer. I think that brewers' curiosity is stirred by the original magic of success and accomplishment. I am encouraged by the fact that learning about yeast science has never diminished my appreciation for the magic of yeast. In fact, the more I learn the more respect I have for the unknown forces that drive and harmonize life itself. The bubbles in my glass of homebrew are now no less special and mysterious than they were in 1970 when I made my first batch of beer. To me the magic continues. I am a sorcerer and yeast is my apprentice.

Having an apprentice is not easy at first. But as you understand why an apprentice behaves the way it does and what it needs, then there is no end to the "sorcery" a brewer can concoct.

This 1989 Special Issue of ***zymurgy*** is not so much a guide to sorcery as it is a guide to the sorcerer's apprentice. Nearly one

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year in production, this special issue on yeast is intended primarily to provide homebrewers with a beginning source of both practical and theoretical information about yeast and brewing. It is by no means a comprehensive study on the subject.

The editors of ***zymurgy*** have tried to include information that is usable and understandable to the beginning brewer, and at the same time provide material and procedures useful for intermediate and advanced brewers who desire to continue their brewing education.

Some of the advanced material, with its chemical formulas and technical terms used routinely by fermentation scientists, may seem intimidating. This material is included because, with scientific information of this caliber, simplification jeopardizes the accuracy and original intent of the author.

As a whole, information in regular issues of ***zymurgy*** is presented on a level that most beginning and intermediate homebrewers can understand. But this Special Yeast Issue has been designed as a resource that will inspire curiosity and further reading and will be referred to and learned from for years to come.

Not since ***zymurgy***'s 1985 Special All-Grain Issue have we attempted to present information on such a technical topic. It is with great satisfaction that we are able to offer to the homebrewing community a special issue of ***zymurgy*** of this quality. The editors especially recognize the professors, students, amateur brewers, professional brewmasters and industry experts who wrote and researched the articles for this 1989 Special Yeast Issue. It would not have been possible without their enthusiasm, support, suggestions and contributions. And finally, we wish to recognize former Associate Editor Tracy Loysen, who was the major force behind putting all the pieces together and making this special issue happen.

I think you all will agree that this special issue of ***zymurgy*** will be a reference for years to come.

ABOUT THE AUTHORS

Stephen N. Ask

comes to Michael Lewis' graduate program in brewing science with a degree in biochemistry from the University of California-Davis. In addition to bringing that background to bear on the microbrewery industry, Ask hopes to develop his skills in the areas of sensory analysis. Ask is currently consulting with local business professionals in preparation for developing a microbrewery or brewpub.

PHOTO COURTESY OF UC-DAVIS

STEPHEN N. ASK

Byron Burch

has been teaching homebrewing and winemaking since 1972 and is the author of *Quality Brewing* and *Brewing Quality Beers*. He is also the owner of Great Fermentations of Santa Rosa. Burch won the AHA's Homebrewer of the Year award in 1986 and is President of the Board of Directors of the AHA Beer Judge Certification Program. The article appearing in this issue of ***zymurgy*** first appeared in the August 1989 issue of *The Beverage People News*.

PHOTO BY MICHAEL LICHTER

BYRON BURCH

George Clayton Cone

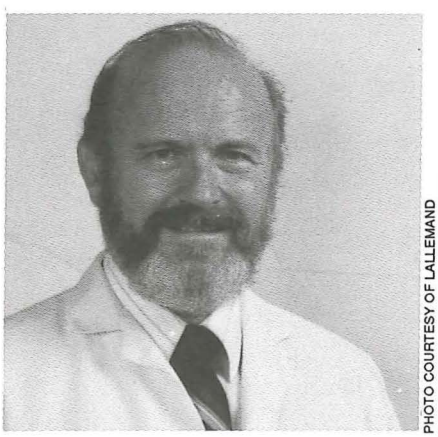
is technical consultant for Lallemand Inc., Montreal, Quebec, Canada, and technical director for American Yeast Inc., Baltimore, Maryland. He has over 35 years experience in commercial yeast production, research and development, as well as industrial applications such as baking, pharmaceuticals, brewing, wine-making and distilling.

Kurt Denke

is a Philadelphia lawyer who would rather baby-sit a cantankerous fermentation than write a brief. He is a partner in Home Sweet Homebrew, a brewing supply shop. Denke is a frequent contributor to ***zymurgy*** and thinks his passionate interest in malt developed as a youngster, when he began drinking lots of Ovaltine.

Fred Eckhardt

is a Portland beer historian, homebrewer and beer enthusiast. His 1969 book, *A Treatise on Lager Beer*, was the first American homebrewing text and the first featuring all-malt brewing in the home. Eckhardt writes a beer column for the *Portland Oregonian*, as well as a column, "The Beer Enthusiast," in *All About Beer*. He travels and lectures on homebrewing and contributes regularly to ***zymurgy*** and *American Brewer*.



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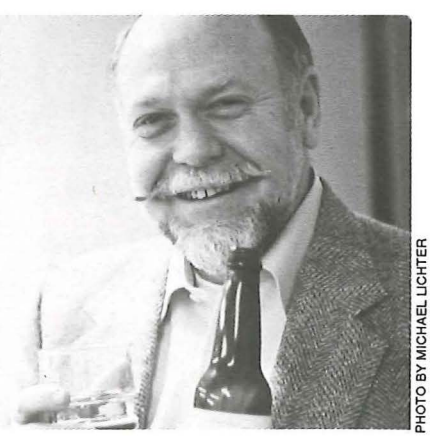

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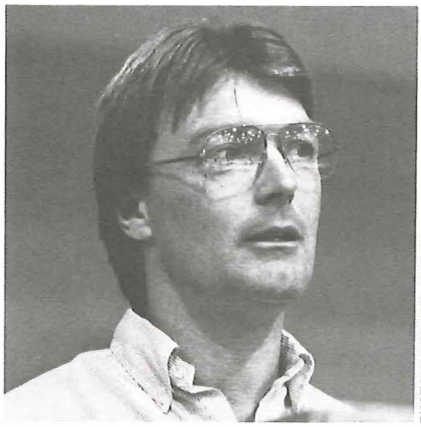

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PAUL FARNSWORTH

Paul Farnsworth

was born and raised in Burton-upon-Trent, England, where he thought fresh air was supposed to smell like boiling wort and the only jobs available were at the breweries. After working in research at the University of California in San Diego he moved to Texas. He now lives in San Antonio, where he teaches fermentation science at the University, helps out at competitions as a certified beer judge and still seeks the perfect ale recipe.

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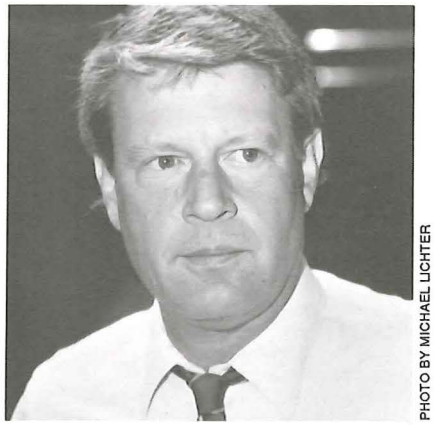
JEAN-XAVIER GUINARD



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GEORGE FIX

George Fix

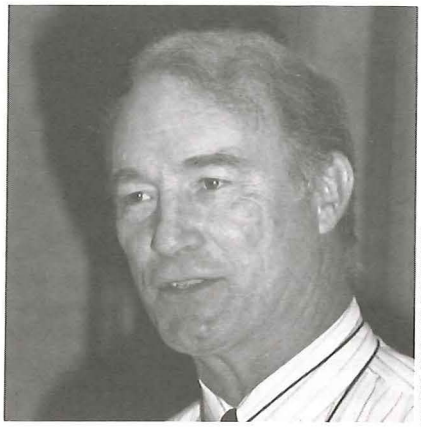
is scientific consultant for the Dallas Brewing Co. He earned his Ph.D. from Harvard University in 1968 and is a professor in the College of Science at the University of Texas at Arlington. Fix has written numerous brewing articles for ***zymurgy***, *American Brewer* and *Home Fermenter Digest*, and is the author of 78 technical publications and three books.

Jean-Xavier Guinard

is a native of France, where he studied at a national institute for the study of industrial food science. He has worked in both the wine and beer industries in Europe. Guinard is continuing his education with Michael Lewis through the Department of Food Science and Technology at UC-Davis. He has completed his doctoral studies on the physiology of yeast and is working on a treatise on lambic brewing.

John Isenhour

began brewing in 1978 while still in college. His first few batches were from a book advocating half malt and half white sugar. Soon he began all-malt extract brewing. He has evolved into a "sterile-technique freak" and constantly scours the universe for sterile technique tips. His latest advances include pure cultured yeast and single-stage fermentation in a 15-gallon glass carboy.



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MICHAEL LEWIS, PH.D.

Michael Lewis, Ph.D.

is a professor of Brewing Science at the University of California-Davis. His membership affiliations include the American Society of Brewing Chemists and the Institute of Brewing (London). He is also a principle in The pub Brewing Co., an equipment supply company. Lewis is the author of numerous papers on brewing, and also teaches and advises dozens of brewers in the microbrewing industry.

PHOTO COURTESY OF JOHN ISENHOUR

JOHN ISENHOUR

Paul Monk, Ph.D.

is a consultant and director of production and research at Intek, Pty. Ltd., where he designed a plant for the production of specialized, high-purity, active-dried yeast cultures for the fermentation industries. He served as head of the Microbiology Research Group with the Australian Wine Research Institute from 1979 to 1987, and holds a Ph.D. in microbial energetics from Sweden.

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PAUL MONK, PH.D.

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MARY G. MIRANDA

Mary G. Miranda

is a graduate of UC-Davis and a 20-year veteran of the Department of Food Science and Technology. She has worked almost 15 years in esoteric areas of yeast taxonomy, evolution and ecology. Miranda has been on staff at Dr. Lewis' laboratory for the last several years. She hopes to develop a pictorial atlas of microbiology that could put the concepts and practices of microbial quality control within the grasp of any interested brewer.

Rodney Morris

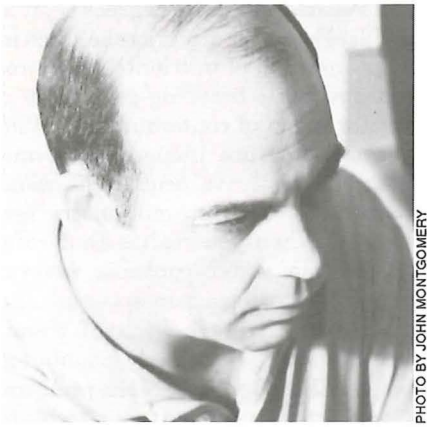
of College Station, Texas, has been brewing for more than 16 years. A Malthopper since the club was formed six years ago, he was previously a Maltose Falcon. Morris became interested in homebrewing while in the army. He developed a taste for European beers but found that the quality varied too much. Among his many accomplishments is the invention of the Recirculating Infusion Mash System.

Pierre Rajotte

has been brewing for more than 10 years. By profession he is a mechanical engineer, but he also serves as a brewing consultant to Le Cheval Blanc (The White Horse) brewpub in Montreal, Quebec, Canada. Pierre has taken microbiology courses in brewing quality control and has 25 different yeast strains in his collection. He also has designed a one-barrel pilot brewery, which is for sale to the public.

Darryl Richman

is happy to call himself a Maltose Falcon. He has been the Brewmaster at Ye Olde Craftie Foxxe brewery and its sister, Der Schlaue Fuchs Altbrauerei, since their founding in 1986. He works nights and weekends as a computer programmer to make ends meet, and occasionally has time to see his wife.



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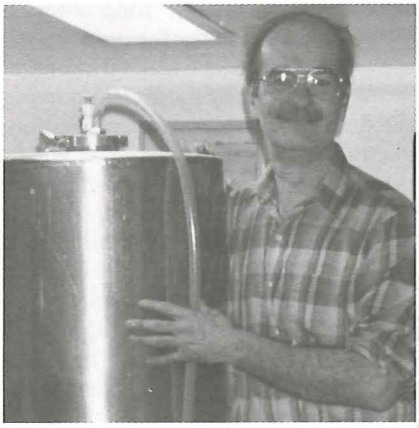

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PIERRE RAJOTTE

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DARRYL RICHMAN

PAUL FARNSWORTH

Healthy Homebrew Starter Cultures

"If I'm doing everything right, how come it still tastes like homebrew?"

As I taste homebrew across the country, I notice some common flavors; some background notes that mark the beer as homebrew. I'm not talking about the usual quirks of zealous overhopping and the injudicious addition of copious amounts of roasted specialty grains. I'm talking about good beer with a background hint of one of the flavors common to many homebrews. This can be a slight phenolic, medicine taste; an inappropriate estery, overripe fruit flavor; an acidic, sour taste on the top of the tongue; or a slight hint of sulfur or cabbage in the smell or taste. Each of these can be caused by poor brewing techniques and the sources have been well-documented in this and other publications. But if you are doing everything right with fresh ingredients, recipes and careful procedures and these flavors are still there, you should turn your attention to your yeast and the method you used to introduce it into the wort.

As I began investigating the source of these flavors it became clear that the beers were being contaminated by low levels of bacteria and wild yeasts, despite heroic sanitization efforts by brewers. I have seen people scrub their arms with undiluted bleach and fill the air with disinfectant fog to levels that rival San Francisco Bay. We don't do this in the microbiology laboratory, and my experience in commercial breweries, particularly the smaller traditional ones, has been that their techniques and equipment would give homebrewers the horrors. These include wet wooden vats, musty, fungus-laden cellars, topping up the fermenter with tap water and scooping out a cupful of fermenting wort by hand after parting the foam with a forearm. Sanitation, at first sight, was at the level where you didn't put a dirty measuring stick into a fermenter of wort; you wiped it off on the leg of your coveralls first! Although these people make a living at brewing and one contaminated batch can ruin a brewer's reputation for generations, they do not have the contamination problems homebrewers see, despite a clearly "inferior" technique.

Those incredible efforts at sanitation may not be necessary during all stages of your brewing. Here's how to work with your yeast to fight off-flavors.

Upon closer inspection the reason becomes clearer. Scrupulous sanitation is used only for the part of the brewing cycle that is highly vulnerable to contamination. The wort chiller piping and the empty fermenters are carefully cleaned and sanitized, and great care is taken with the pitching technique, (the addition of yeast to the cooled wort). Merely adding the right type of yeast is not enough; you must add the right amount at the right time and it must have been in the right place before that. The stage at which the wort is susceptible to infection is the period after the boil and before the yeast is actively growing in it. Once the yeast is actively fermenting (a head is formed) the yeast has removed much of the oxygen, preventing many contaminants from growing. The yeast also has acidified the wort, inhibiting bacteria. There are so many millions of rapidly growing yeast cells that they overwhelm competing microbes. This is why the apparently unsanitary practices of old breweries were not disastrous. Once the wort is fermenting vigorously the yeast prevents anything else from growing, thereby protecting the wort from spoiling.

To protect our homebrew we must add a large amount of healthy, uncontaminated, actively growing yeast as soon as the wort is cool enough. Breweries add yeast while the fermenter is still filling so the yeast is working even before the vat is full. Once the temperature of the wort has fallen below 100 degrees F (37 degrees C), it is an ideal home for any microbe. Rich in sugar and full of nutrients, wort provides a fertile breeding ground for a veritable zoo of contaminants. Wild yeast spores are induced to germinate, fungi thrive and a thousand bacteria can turn into millions in a few hours. When you realize that safe, "good" tap water contains several thousand bacteria per spoonful and that every square inch of clean, healthy skin is similarly populated, you see the magnitude of the problem. Cool wort is exceedingly vulnerable to contamination and the only way to

protect it is to add so many active yeast cells that they muscle out any contamination.

Two homebrewing strategies emerge from this. One is to keep the time between the completion of the boiling and the addition of yeast as short as possible. This is reflected in the homebrew tradition that actively cooling the wort is better than leaving it outside until the next day. Note that after the boil, if the lid is still on the kettle the hot wort is sterile. You can leave it to steep and settle. However, as soon as you cool it and stick things like siphon tubes into it, you have introduced contaminants that will begin to grow. Cooling the wort before transferring it to the fermenter, using ice immersion or a copper cooling coil placed inside the boiling pot vastly increases the chance of contamination. No matter how carefully done, the act of transferring the nutrient-rich cool wort from kettle to fermenter will pick up lurking microbes that sometimes will spoil beer and sometimes will not, it's your gamble. The quicker you get the yeast actively fermenting in the cooled wort, the smaller will be this window of opportunity for infection.

Not only must the yeast be added as soon as the wort is chilled, but also you must add yeast that is active, healthy and in sufficient amounts to begin to grow immediately. Yeast growth that is sufficient to suppress the growth of spoilage organisms requires adding 10 million actively growing yeast cells per teaspoon of wort (two million cells per milliliter.) This means a total of 40 billion cells in five gallons. When I looked at how many live cells were in a commercially available package of yeast, I found enormous variation, not only in how many were in the package but also in the kinds (see Table 1).

Experiments with storage conditions suggested why the number of live yeasts per package varied: the yeast died during storage and the death rate was dependent on storage temperature. I investigated three different packaging styles–dry yeast in foil packages, liquid yeast in foil pouches (as sold by Wyeast or Williams) and liquid yeast in plastic tubes (as sold by Yeaster or M. eV.). Each had a different optimum storage temperature and each showed a significant death rate if not kept at its optimum temperature. As Table 2 shows, dry yeast is best kept in the cold and reactivated in very hot water before using. Liquid yeast in foil packets is best stored in the cold and reactivated at 90 degrees F (32 degrees C). Liquid yeast in plastic tubes dies very quickly in the cold and is best stored at 60 degrees F (15 degrees C) and activated at 90 degrees F (32 degrees C).

Assuming yeast is not stored at its optimum temperature, the dry yeast survives better than that in liquid. If kept cold, only 20 percent of the dry yeast is dead after 12 months, but if left too warm, it is possible to kill most of it in one year.

The implication is clear. If you get yeast that has sat on the shelf for years, or has been in a non-airconditioned warehouse, its viability will be so compromised that one package will not provide enough yeast cells to protect the fermentation from infection by other microbes. Yeast in liquid in foil pouches is less hardy and will last at best a few months in the cold or a few weeks at room temperature. It will not survive a three-day trip through the mail in summer to hot parts of the country. Yeast in liquid in plastic tubes is even more fragile (I suspect because of the way it is prepared and the liquid it is shipped in). It will be harmed seriously by a few weeks in the cold or a few days at elevated temperatures. Oddly, yeast in tubes survives best at a temperature just below room temperature (60 degrees F or 15 degrees C). Again, be aware of storage and shipping conditions if you wish to use a package of yeast to make an instant, active yeast army to fight off the contaminants in

Table 1.
Yeast manufacturers listed in order of "quality"
(Degree of contamination by wild yeast and bacteria)

High Quality
Edme
Williams

Medium Quality
Munton & Fison
Vierka

Low Quality
Red Star
Doric

NOTE: This ranking is based on laboratory analysis of samples of these brands bought at random across the country and grown on malt, lysine or actidione agar plates. The results here represent the author's opinion and, as wide variation from package to package is seen, your results may vary.

Table 2. Optimum storage temperature and reactivation temperature for yeast in different packaging styles

Package Style	Optimum Storage Temperature	Optimum Reactivation Temperature
Dry yeast in foil pack	40 degrees F (5 degrees C)	100 degrees F in water (35 degrees C)
Liquid in foil pack	38 degrees F (4 degrees C)	90 degrees F in foil pack (30 degrees C)
Liquid in plastic tubes	60 degrees F (14 degrees C)	90 degrees in wort supplied with kit (30 degrees C)

Table 3.
Death rates of yeast at various temperatures for different packaging styles

Package Style	**Cold** (always refrigerated) **38 degrees F** (4 degrees C)	**Room** (air-conditioned room) **68 degrees F** (20 degrees C)	**Warm** (shipping cross country) **100 degrees F** (35 degrees C)
Dry yeast Foil pack	20% dead in 12 months	90% dead in 12 months	All dead in 12 months
Liquid yeast Foil pack	90% dead in 6 months	90% dead in 2 weeks	All dead in 3 days
Liquid yeast Plastic tube	90% dead in 2 weeks	90% dead in 3 months	All dead in 2 days

your wort. Table 3 summarizes these results.

To follow our strategy of adding 40 billion actively growing yeast cells as soon as the wort is chilled, we must take into account the packaging style and its prior history. A large package (10 grams) of dried yeast contains theoretically between 40 and 100 billion cells and should be adequate. In practice the actual contents are always less than this, and these dried, dormant yeast cells need to be raised from their slumber before they can grow and overwhelm the spoilers. The revival of dried yeast should ideally be done in two steps; one to get them wet again (rehydration) and the second to get them growing (the addition of sugar). Rehydration should be done by adding the powdered yeast to 1/2 cup of hot (100 degrees F or 37 degrees C) water for five to 10 minutes. Following this, malt or sugar can be added or the wet yeast added to wort. Sprinkling dry yeast from the package into the wort may work or may produce a lag time while the surviving dormant yeast gets organized and grows to the required numbers. Again, you are gambling that it will grow quickly enough.

A compromise may be to follow the baker's strategy of proofing the yeast. First, rehydrate the yeast under optimal conditions. The latest data on this from Intek, an Australian dried-yeast producer who is just entering the U.S. market, are as follows: Rehydrate the dried yeast in one-half cup of water. Clean water between 95 degrees F and 104 degrees F (35 and 40 degrees C) should be used. City water supplies containing high concentrations of chlorine will inactivate dried yeast during rehydration. Chlorine can be removed by boiling. Cold water will significantly decrease the viability of dried yeast during rehydration. It is advisable not to rehydrate yeast in wort because compounds extracted from hops are antiseptic and can decrease yeast viability while the yeast is being rehydrated. Slowly sprinkle the dried yeast into the warm water while gently stirring to disperse the yeast. Allow to stand for 15 minutes.

Add 1 1/2 cups of wort to the rehydrated yeast to adjust temperature to that of the wort to be inoculated. Rapid temperature changes greater

Table 4.
Amount of yeast required to obtain optimal pitching rates*

Yeast type and condition	Amount required for five gallons
Dry yeast in package less than six months old	One to 10 packs depending on manufacturer and storage conditions
Liquid yeast in foil pack activated and left until pack is fully swollen	10 packs if pack was stored under optimal conditions and didn't warm up during shipping
Liquid yeast in plastic tube reactivated in two cups as directed and left until head just falls	Culture from one tube if storage conditions left any live cells and brewer didn't contaminate culture during slow phase of starter growth
Two cup liquid starter culture made from pure yeast stored on agar	Two cups if not contaminated during slow phase of starter growth
Yeast from bottom of recent primary fermentation stored for less than three days in the cold	One cup

* The best flavors and maximum yeast growth to suppress the growth of spoilage organisms requires pitching with two million actively growing yeast cells per milliliter of wort. This means a total of 40 billion cells in five gallons.

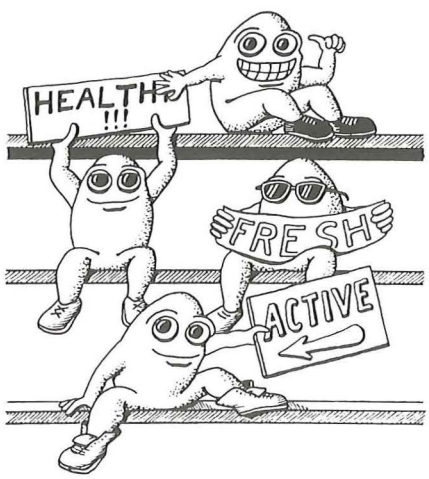
than 18 degrees F (10 degrees C) at a time to any yeast suspension will cause a temperature shock. Temperature shock forms tiny mutants with impaired sugar uptake. Fermentations containing these mutants will be slow and possibly incomplete, with poor settling properties. Yeast should not be pitched into wort at temperatures lower than 59 degrees F (15 degrees C). Use the rehydrated yeast within one hour of rehydration. If this starter isn't foaming vigorously within an hour, it lacks enough live yeast and you should discard it. Do not save such a starter for more than one hour. There is a chance you will have contaminated it and if the yeast doesn't start to grow straight away the contaminants will grow just as they would in a five-gallon batch. The advantage of this method is that you know whether the yeast is going to work before you pitch it and you haven't ruined five gallons. However, you do face a frantic search for good yeast if your starter fails and you are in the middle of the wort boil!

Because it is most often free from contamination, liquid culture yeast sealed in a foil pouch theoretically is the best method for making a yeast starter. There is no chance of getting your grubby paws into it to contaminate it. Unfortunately, even if you get a fresh pack stored under ideal conditions, there is not enough in a 40-milliliter package to give a protected fermentation in five gallons. There is only one-sixth cup of starter liquid in the foil pouch and this does not contain enough yeast to start five gallons of wort. If you do not use the starter method, make sure the pouch is very swollen. This is difficult to orchestrate to coincide with the time your wort is ready, because it may take from one to 10 days to swell. If you refrigerate the pack after activating it, you will slow down or kill the yeast. A better idea may be to open the pack and use it to make two cups of starter.

If you are using the yeast in liquid cultures and follow the directions to make two cups of starter, you will eventually end up with enough cells. This may take from two to seven days depending on prior storage conditions. Wait until the starter has generated a head that is beginning to fall down, then use immediately. The danger in this method is that, just like your five-gallon batch, the two-cup starter is vulnerable to contamination until the yeast is actively growing. Again, fresh, well-stored cultures (see Table 3) will grow the fastest and minimize the chance of infection.

Propagating your own yeasts and making a two-cup starter in hopped wort, inoculated from a pure culture stored on agar slants or dishes, is the best and also the most difficult method. I have begun to train people with no science background to do this with a 75 percent success rate on the first attempt. I encourage all brewers to take a microbiologist to lunch to show you how to subculture yeasts; the techniques are simple and the equipment minimal. Again, the danger is in contaminating the starter before the yeasts take over.

The easiest and safest way to get a yeast starter is to repitch with yeast from a prior fermentation, as has been industry practice for centuries. A cup of sediment from the bottom of the primary of a successful fermentation will keep for three days or more in the cold. If you brew regularly you can repitch the same yeast over and over in successive batches. As soon as you notice a slowing of fermentation, or odd smells or flavors, you must discard the yeast and start again with some from another proven source. I do not recommend washing the yeast to purify it, as is done in many breweries, unless you have much experience as a microbiologist. The main disadvantage of this method of reusing the yeast is that you must brew regularly, and that's not all bad!



JEAN-XAVIER GUINARD, MARY MIRANDA
AND MICHAEL J. LEWIS, PH.D.

Yeast Biology and Beer Fermentation

Comments on Yeast Physiology and Behavior

We now prize yeast as the magician that turns wort into beer, but the relationship between microorganisms and organic materials was not recognized until the middle of the 19th century. However, microbial processes have been employed since prehistoric times to provide humankind with fermented dairy products, pickled vegetables and meats, and leavened breads as well as beers and wines. Fermentation sometimes is called "controlled spoilage." Through the curiosity and perseverance of artisans and a few scientists, we now have developed modern technologies, based on the understanding of these vital microbial processes that allow us to control native fermentations to make the variety of quality fermented products we enjoy today. Beer is no exception.

History

Although beer making is one of the oldest crafts known to man, the nature of fermentation was not made clear until 1836, when Cagniard-Latour proposed that sugar fermentation was the result of yeast activity. Beer was fermented with top-fermenting yeast until the middle of the 19th century when the knowledge of bottom-fermenting yeast, first known by Bavarian brewers, became widespread. Tradition has it that a Bavarian monk introduced this yeast and fermentation practice to Czechoslovakia, thereby establishing Plžen as a center for bottom-fermented beers. Jacobsen, a Danish brewer, accomplished the same by taking bottom-fermenting yeast from Munich to Copenhagen and shortly afterward the yeast crossed the Atlantic to our shores. Pasteur's studies on the microbiology of beer in 1876 and the pioneering work of Hansen (1880s), who isolated and maintained pure yeast cultures at the Carlsberg brewery in Copenhagen, ensured for the first time that the recognition, testing and maintenance of quality strains of brewer's yeast followed scientific principles.

Ecology and Taxonomy

Yeasts in general are relatively abundant in nature. They can be found in the air, water and soil, but are most commonly associated with plant substrates that provide nutrients such as carbohydrates, amino acids and organic acids. Yeasts cannot grow without preformed organic compounds because they are not photosynthetic. The criteria used in the classification (taxonomy) of yeasts may include morphological, physiological, biochemical and sometimes ecological characteristics. The basic units of classification are the genus, the species and the strain. Examples of genus names are *Saccharomyces*, *Dekkera* or *Brettanomyces*. About 37 genera of yeasts are currently accepted. Yeasts used by brewers are all in the genus *Saccharomyces*.

They may be small, but they have a life of their own. You're about to observe the inner workings of yeast, in microscopic detail.

The species is the particular kind of yeast within a genus that can be distinguished by standard taxonomic methods. Today we recognize about 500 species of yeasts or individual types of yeast. The major brewing species are *Saccharomyces cerevisiae*, *Saccharomyces carlsbergensis* (synonymous with *Saccharomyces uvarum*) and *Saccharomyces delbruckii*, although a number of different species names may be found in the brewing literature. A yeast species is a collection of strains, all of which are taxonomically identical, but displaying strain differences that are immensely important to brewers and the particular kind of beer they produce. Thus, commercial preparations of ale yeasts are different strains of the species *Saccharomyces cerevisiae*. Strain variations may include growth rate, temperature tolerance, flocculation character (i.e., mechanical performance) and production of a multitude of flavor compounds (sensory performance). A brewer selects a yeast based on these criteria.

Life Cycle

Yeasts are single-celled microorganisms that grow and reproduce by budding. A bud is a small lateral protrusion or extension from a mature cell. This extension increases in size as the essential cell materials and machinery are distributed between the mother cell (initial cell) and the daughter cell (bud). When the distribution of cellular contents is complete, the bud is sealed off and the new yeast cell assumes an independent life. Reproduction by budding is virtually unique to yeast and is the only way yeast mass and number of yeast cells increase during a brewery fermentation. Some yeasts form sexual spores in specialized structures such as an ascus or a basidium. When released, these spores may fuse with spores of a compatible mating type to continue their life cycle. Yeasts that accomplish this sexual cycle are called perfect yeast. But many yeasts are ancient and less competent forms that have lost a demonstrable sexual state; they are said to be imperfect. Most brewing strains retain only a remnant of their sexual capabilities, enjoying instead the luxury of life in beer and the well-being of domestication by humans.

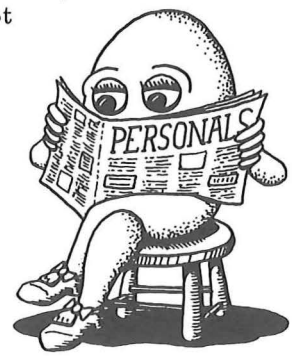
Cytology

Yeasts are fungi. Fungi are nonphotosynthetic organisms with a rigid cell wall that exist as single cells, in chains or as a body of grouped cells called mycelium. Yeasts are eukaryotic organisms, just as humans are. Bacteria, which are less physiologically complex, are called prokaryotic. As eukaryotes, yeasts have a true nucleus that is completely delimited from the rest of the cell cytoplasm by a porous unit membrane. The genetic material is located in the nucleus. Outside the nucleus, various specialized structures and organelles exist. For example, vacuoles for storage of certain amino acids or for excretion of waste products are set apart from the cytoplasm by a special membrane. Mitochondria function under aerobic conditions, acting as complex powerhouses with extensive substructures to harness the energy locked in carbohydrate molecules such as glucose, sucrose and maltose. These organelles are even able to grow and divide autonomously as cellular needs demand. Under fermentative conditions, the mitochondria degenerate and do not replicate themselves, because they are not needed. Carbohydrates are converted to energy by the relatively inefficient, but universal, process of glycolysis. This is accomplished by a complex series of single enzymes present in the basic cellular cytoplasm.

The blueprint for most of the cell's enzymes is encoded in the nucleus of the yeast cell in a highly complex and conserved compound called DNA (deoxyribonucleic acid), usually found as a double stranded helical moiety (part of a helix) in the chromosomes of the cell. When the cells are placed in a suitable growth environment, more enzymes are needed and a copy of their blueprints is made from the nuclear DNA. This copy is made of RNA (ribonucleic acid), usually a single-stranded structure. This copy is called messenger RNA (m-RNA).

Protein synthesis occurs in organelles in the cytoplasm called ribosomes. These function like a weaving loom. Two components of the ribosome fit together, holding a copy of the nuclear blueprint (m-RNA). Another specialized type of nucleic acid, transfer RNA (t-RNA) fetches the specified amino acid to the ribosome where it attaches to other amino acids. This amino acid chain grows unit by unit into a complex polypeptide until the pattern is complete; the protein thus formed is then released and the ribosome complex breaks apart.

The variety and chemical nature of the amino acids (there are only about 20 different amino acids found in naturally occurring proteins) impart particular physical structures and unique properties to the proteins. Life activities are in essence the functioning of proteins; for example, proteins are both structural elements of the cell and enzymes that catalyze cellular reactions. In a highly active cell, ribosomes can be seen in a network of organized arrays called the endoplasmic reticulum. Often the endoplasmic reticulum can be seen connecting with the nuclear membrane and/or the cytoplasmic membrane. Surrounding the entire cell is the cytoplasmic or cell membrane that controls the transport of materials into and out of the cell. Finally,



the entire cell and its contents are contained within a rigid cell wall made of fibrillar polymers of glucose and mannose. Some yeasts, especially those found in air or water, have an external polysaccharide capsule of less defined structure and composition. Figure 1 illustrates a cross section of a brewers yeast cell (*Saccharomyces cerevisiae*) and the organelles mentioned.

Yeast Growth and Development

What brewers must remember with regard to yeast behavior during fermentation is that the metabolism of yeast is not designed to make beer, but rather is geared toward making yeast. Yeast metabolism is comprised of many enzymatic reactions that the cell has organized into carefully regulated biochemical pathways. Much of this regulation involves compartmentalization of metabolic sequences in organelles such as the mitochondria. Another level of regulation involves controlling the amount and/or efficiency of the proteins that mediate the reactions (enzymes). An important example of a metabolic sequence is glycolysis, where fermenting yeast derives energy from carbohydrates (sugars) in the form of ATP (adenosine triphosphate) from this pathway. ATP is one form of high-energy phosphate that supplies the energy for synthetic cell reactions. Glycolysis also forms compounds that act as building blocks or precursors for necessary cellular components, formed by subsequent assembly reactions.

For mere maintenance of the cell, glycolysis serves the yeast well. Yeast can exist on sugars almost exclusively. Brewer's yeast can utilize a variety of simple sugars including glucose, fructose, mannose and galactose. Maltose, sucrose, raffinose and in some cases maltotriose and melibiose can be utilized as well, because the yeast has systems to transport and transform these molecules into glucose, which can then be used in glycolysis. However, yeast requires more than sugar for growth; it requires nitrogen, oxygen, minerals and other growth factors. Ammonium ions, most amino acids and small polypeptides present in wort meet the nitrogen requirement of brewer's yeast. Significant amounts of phosphate and sulfate also are required by brewers yeast, as well as minute amounts of potassium, calcium, iron, magnesium, manganese, copper and zinc in the form of salts. The growth factors (vitamins) required vary from strain to strain both in amount and kind and can be quite strain specific. Biotin is required almost universally in very small amounts and one or more of thiamine, inositol, pyridoxine, niacin, pantothenic, and p-amino-benzoic acids may be needed. Molecular oxygen is required for the biosynthesis of unsaturated fatty acids and sterols such as ergosterol, which are present in yeast cell membranes. Among other functions, these sterols impart alcohol tolerance to the yeast. All these nutrient materials, including oxygen, must be provided by the brewer's wort if adequate yeast growth is to be supported for proper fermentation.

Growth of yeast results in an increase in cell mass or weight as well as in the total number of cells. Upon pitching of yeast into a batch of wort, yeast growth follows three phases. As the inoculum adapts to its new environment, there is a lag phase during which time the yeast synthesizes the enzymes it needs to reinitiate growth. This phase is very significant because oxygen is rapidly taken up in the lag phase and utilization of nutrients, especially phosphate, causes the pH to drop before the actual onset of growth and fermentation. Once these systems are functional and the yeast has adapted to its new environment, the yeast begins to grow at a rapid rate; this is called the logarithmic or exponential phase of growth, though there may be only a limited amount of truly logarithmic growth occurring in a brewery fermentation. During this exponential phase, the population of yeast will increase in proportion to the size of the initial inoculum and the nutrients available in the wort. Commercially, one to three doublings of the inoculum population will occur. Eventually, as any one nutrient or combination of nutrients is depleted and retarding concentrations of fermentation products accumulate, the yeast population stabilizes in the stationary phase. In commercial beer production, flocculation occurs as the yeast enters the stationary phase that

serves to clarify the green beer. The green beer is then cooled and transferred to storage.

Physiology of Fermentation

Glucose, ATP and pyridine nucleotides (NAD^+ and $NADP^+$) are the universal currencies or units of energy and energy transfer for all biological systems. Wort contains primarily maltose, derived from the action of a-amylase and b-amylase on starch during mashing. To be useful to the yeast, this disaccharide must be transported into the yeast cell and broken down to two molecules of glucose. The 6-carbon glucose molecule is then split again (hence the term glycolysis=glucose lysis), by way of the Embden-Meyerhoff-Parnas pathway, into two 3-carbon molecules, the last one of which is called pyruvic acid. Glycolysis also yields two ATP molecules and reduced pyridine nucleotides (NADH and NADPH), which are used for other energy-consuming (synthetic) cell activities. Glycolysis occurs both in the presence of oxygen (respiration) and in the absence of oxygen (fermentation) to form pyruvate.

The fate of pyruvate depends on the environment of the yeast. In the presence of high levels of fermentable sugars (above 0.5 percent in the case of brewers yeast) and/or low concentrations of oxygen, the yeast transforms the pyruvate to alcohol and CO_2 and excretes it. This reaction is well known in the brewery. On the other hand, if the level of fermentable sugars is low and there is ample oxygen, the yeast will respire the pyruvate in the specialized mitochondria, reducing the 3-carbon compound (i.e., pyruvate) completely to CO_2 and H_2O. This releases a great deal more of the energy bound up in the original glucose. The greater efficiency of respiratory metabolism is much to the yeast's benefit and a large increase in biomass occurs. This is exemplified by the commercial production of baker's yeast from molasses where the fermentation is carried out in highly aerated vessels and the molasses is pulsed into the vessels in small increments that maintain the total concentration of fermentable carbohydrate at or below 0.5 percent.

In a typical brewery fermentation, pyruvic acid from glycolysis is first decarboxylated, yielding CO_2 (excreted) and acetaldehyde. The yeast further reduces the acetaldehyde to ethanol (excreted) with the enzyme alcohol dehydrogenase. This reaction is used to regenerate NAD^+, which is a key energy carrier in glycolysis. A summary of fermentation reactions is presented in Figure 2.

Consistency of beer flavor in the fermentation stage depends on the kinds and amounts of organic molecules excreted by the yeast; that is, materials other than alcohol and CO_2. Collectively these flavor compounds often are secondary metabolites formed in small quantities at different points in the main fermentation. However incidental they may be to the yeast, they are crucially important to beer flavor. They account for only a small proportion of the total sugars fermented, but they comprise many different kinds of compounds in very low concentrations, many with very low detection thresholds (i.e., easily tasted at low concentration). These secondary metabolites originate in many different metabolic sequences in various parts of the cell. They have different functions and respond in different ways to the environment imposed by the fermentation conditions.

All these metabolic sequences in which the secondary metabolites originate are under the control of the yeast's genetic material. This is why different yeasts make different contributions to beer flavor. This also partially explains why it is not possible to exactly predict what influence the

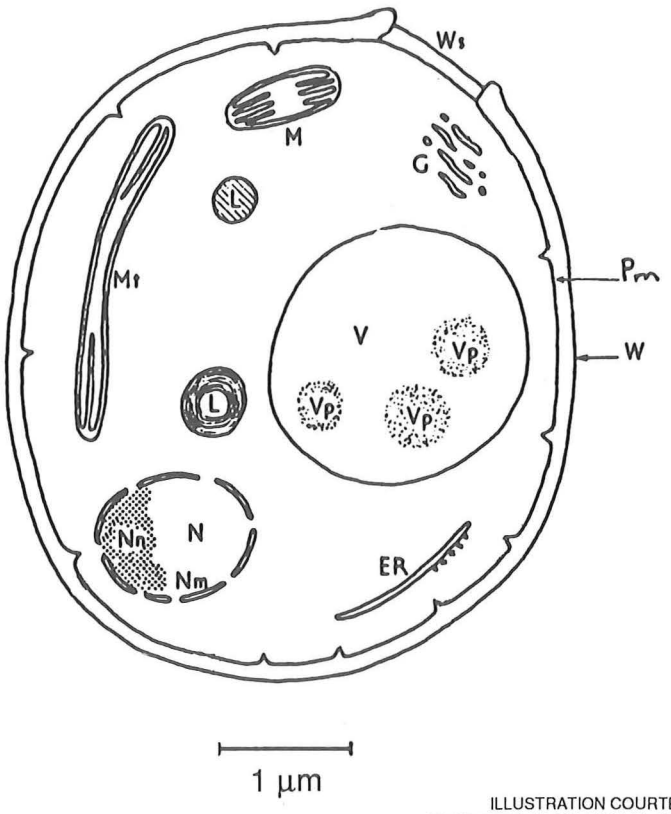


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Figure 1.

The yeast cell and its organelles in cross section.

ER = endoplasmic reticulum with ribosomes;
G = Golgi complex;
L = liposome;
M = mitochondria;
N = nucleus;
Nm = nuclear membrane;
Nn = nucleolus;
Pm = plasma membrane;
V = vacuole;
Vp = vacuole particle;
W = cell wall
Ws = bud scar.

The bar represents one micrometer.

environment (fermentation temperature, for example) will have on production of beer flavor compounds. Some 90 percent of fermented wort sugar is transformed to alcohol and CO_2; the remaining 10 percent is divided about equally between yeast growth and production of flavor compounds. Generally speaking, anything that promotes yeast growth relative to fermentation will tend to reduce the amount of flavor compounds produced by directing the carbon of the fermented sugar into yeast mass. Such things as highly aerated wort, low yeast inoculum, ideal growth temperature, very nitrogenous wort, for example, would have this moderating effect. Conversely, suppressing yeast growth relative to fermentation will tend to have the opposite effect; e.g., very high or low temperatures, high yeast pitching rate, high gravity wort and unaerated worts will tend to promote production of yeast flavor compounds. Thus fermentation may be viewed as a pipe through which carbon from sugar flows on its way to alcohol and CO_2; the pipe has small holes in it through which some carbon can escape as flavor compounds. The pressure in the pipe, how full it is and the length of time it is in use all help determine the amount of leakage of flavor compounds into the beer.

Some of the flavor compounds produced by brewers yeast include small amounts of glycerol, succinic acid, fusel oils (higher alcohols), 2,3-butanediol and traces of acetaldehyde, acetic acid and lactic acid (among many other compounds), depending on the strain. Some of the pyruvic acid is converted into a-acetolactate, which is excreted. Outside the cell, its oxidation to undesirable buttery-smelling diacetyl is especially problematic in lager beers. Other off-flavors resulting from yeast metabolism include the production of hydrogen sulfide from organic sulfur compounds or sulfate ions during fermentation. Lager beers again suffer more from H_2S production than ales, to an extent that varies with wort composition, yeast strain and fermentation temperature. The "lagering" process (low-temperature storage in the presence of yeast) reduces the final concentration of H_2S and diacetyl in the finished product. Dimethyl sulfoxide (DMS) is another undesirable product of wort metabolism by yeast. This sweet corn or garlicky smelling compound is produced from S-methyl methionine, a heat-labile component of malt, or from dimethyl sulfoxide (DMS) produced by oxidation reactions during malt kilning or in the kettle boil.

Fermentation bouquet arises from a host of volatile compounds among which higher alcohols and esters feature prominently. Higher alcohols are simply alcohols of higher molecular weight and complexity than ethanol (the common alcohol of beer). As ethanol is made from pyruvic acid, so higher alcohols are made from acids similar to pyruvate but of higher molecular weight. The enzymes involved are the same in all cases. The acids that can be transformed to higher alcohols, for the most part, arise from pathways that synthesize amino acids. Esters also contribute to "fermentation bouquet" of both ales and lagers and are formed by reactions between alcohols and acids. Because the most abundant alcohol is ethanol and the most common activated acid is acetic acid (as acetyl coenzyme A), the most abundant ester in beer is ethyl acetate. The involvement of fatty acids in ester formation suggests yeast must have initial access to aerated wort in order to form the necessary precursors for esters. However, active acetate and ethanol both are metabolically very close to pyruvate and a close relationship between wort aeration and ester formation is not suggested here.

In contrast, under respiratory conditions of low sugar concentration and abundant oxygen, two metabolic systems that are essentially shut down under fermentative conditions take center stage. These are the tricarboxylic acid (TCA), or Kreb's cycle, and the cytochrome or electron transport system. These are located in the mitochondria. By the intervention of these two systems, pyruvic acid produced by glycolysis is metabolized, not to alcohol and CO_2, but to CO_2 and water using oxygen itself as the final oxidizer. The net effect is to harness the energy of glucose with a much higher yield of energy per sugar molecule than alcoholic fermentation. Thus, the TCA cycle and electron transport system (respiration) produce many more ATP molecules than fermentation: the oxidative respiration of one molecule of glucose by yeast generates 28 molecules of ATP, whereas anaerobic fermentation produces only two molecules of ATP.

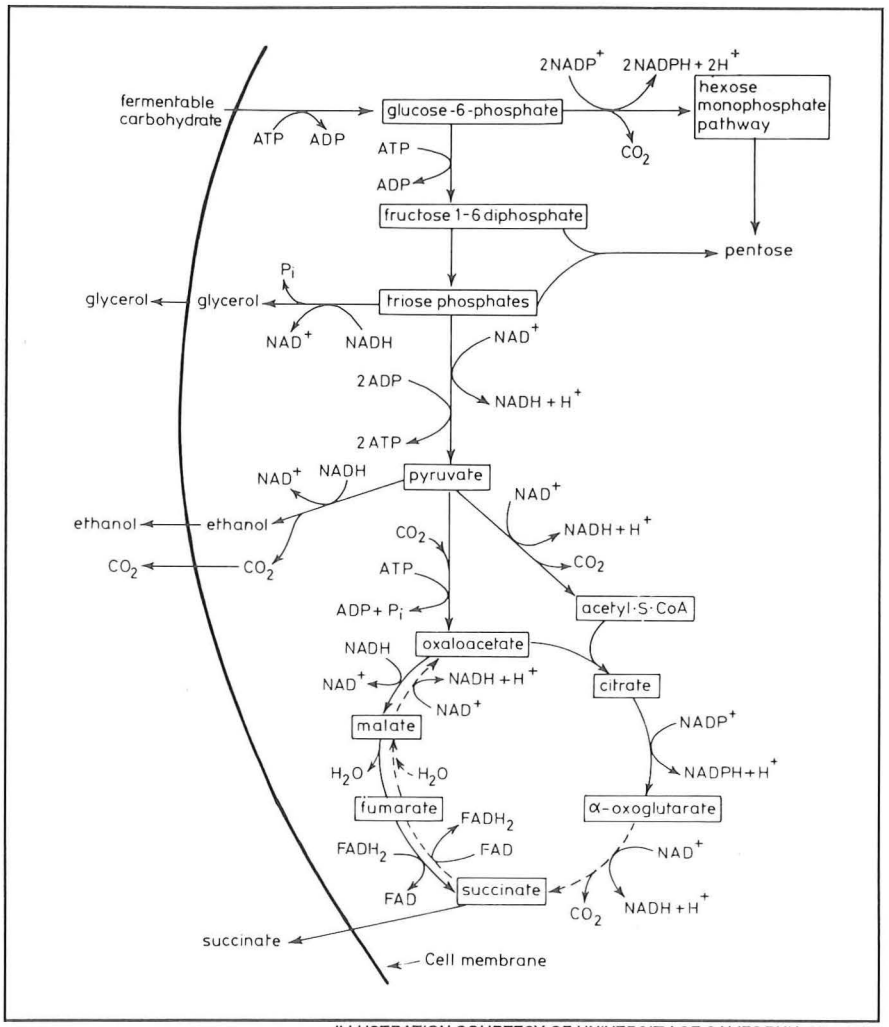
Carbohydrate metabolism is carefully regulated in yeast. Because glucose utilization yields more energy by aerobic respiration than by alcoholic fermentation, yeast will respire whenever it can, especially in the presence of high oxygen and low sugar concentrations. This phenomenon is known as the Pasteur Effect. On the other hand, glucose concentrations in excess of 0.5 percent or so, even in the presence of oxygen, are fermented by yeast via the glycolytic pathway into ethanol and CO_2. This phenomenon is known as the Crabtree effect or catabolite repression.

Flocculation

The yeast cell wall has important implications in brewing, primarily with regard to yeast flocculation at the end of fermentation. The complex character of yeast flocculation is determined by genetic, nutritional and environmental factors, which are incompletely understood. Yeast cells have a rigid, complex cell wall, composed of polymers of mannose and glucose called mannans and glucans. These polysaccharides are cross-linked with proteins and phosphate moieties. Certain strains of brewer's yeast, both *Saccharomyces cerevisiae* and *Saccharomyces carlsbergensis,* spontaneously aggregate during the stationary phase that follows active fermentation to form clumps of yeast called flocs. This flocculation character may be a major criterion in the selection of a yeast strain for the production of a given beer. Flocculation is genetically determined in the nature of the yeast, but also is affected by some environmental factors. For example, the presence of fermentable sugars inhibits flocculation of yeast in wort. As the pH drops during fermentation, flocculation occurs more readily because the overall negative charge on the yeast cell becomes neutralized. Some hop substances also promote floc formation. Two theories currently account for the phenomenon

Figure 2.

A summary of glucose metabolism in yeast. Glycolysis includes all reactions from glucose-6-phosphate to pyruvate; alcoholic fermentation is represented by the reactions branching left from pyruvate and oxidative metabolism of pyruvate is indicated in the cycle branching right from pyruvate.



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of flocculation. The first proposes that calcium ions, which have a double positive charge, mediate flocculation by forming bridges between the negatively charged yeast cells. Carboxyl groups of organic acids (-COO^-) or phosphate groups (-PO_4^{-3}) in the surface layers of the yeast cell wall would be the functional groups involved in floc formation through this calcium ion bridging. A second theory proposes that proteins with lectinlike activity and cell wall carbohydrates (mannans and glucans) mediate flocculation through magneticlike chemical attractions known as hydrogen bonding.

The Distinction Between Ale and Lager Yeast

Ales were probably the historical prototype of fermented barley beverages because the strains of yeast involved in ale brewing, *Saccharomyces cerevisiae*, are less temperature sensitive. These yeast strains grow well at temperatures up to 100 degrees F (37.78 degrees C), although the typical fermentation temperature for ales ranges from 50 degrees to 65 degrees F (10 to 18.33 degrees C), which lager yeast cannot tolerate. Because of their rapid growth, ale yeasts tend to crop to the top in a dense head and are therefore referred to as "top" yeast or top-fermenting yeast. Lager beers are fermented at lower temperatures, 48 to 54 degrees F (8.88 to 12.22 degrees C), by yeast strains classified officially as *Saccharomyces uvarum*, though they are traditionally called *Saccharomyces carlsbergensis*. Lager yeasts grow less rapidly than ale yeasts under commonly used conditions, and with less surface foam they tend to flocculate to the bottom of the fermentation vessel as fermentation nears completion. They are therefore called "bottom" yeast or bottom-fermenting yeast. The distinction between top and bottom yeast is academic today, merely a reflection of a yeast's ability to associate with the bubbles of CO_2 as it rises to the surface under certain traditional conditions. In traditional ale brewing, of course, top cropping was a historically important means of strain selection and maintenance. Brewers recovered the top-cropping yeast by skimming it from the surface for reuse in subsequent fermentations. In modern vessels, ale and lager yeasts crop to the bottom.

Factors Affecting Fermentation

Fermentation rate and extent, flocculation, flavor quality and flavor stability of the resulting beer are affected by three kinds of factors: those related to yeast, the wort and the imposed conditions. Many of these have been referred to already in this article. Chief among them are the yeast strain, its condition, age and amount, all of which affect the fermentation rate, flocculation, stability and flavor. Indeed, control of the yeast is one of the most difficult things brewers do as they strive for consistency. The amount of yeast added to the wort must be sufficient to achieve the proper cell density after growth. Addition of an excessive amount of yeast, as well as being economically unwise, can impart "yeast bite" if the excess yeast autolyzes in the beer. Contact of the yeast with oxygen before pitching is especially important for fermentation performance and ethanol tolerance, and the wort must provide sufficient but not excessive nutrients for growth. Only yeast in suspension

effects fermentation. The size and geometry of the fermentation vessel affects distribution of the yeast in the fermenting wort, especially in cylindro-conical vessels, through agitation and mixing caused by release of CO_2 bubbles. Finally, temperature and pressure, because they affect the rate of biochemical reactions, are major determinants of the rate of fermentation and the production of flavor compounds. When temperature and pressure fall outside normal ranges, they may stress the yeast and induce stuck fermentations or off-flavors.

Genetic Engineering to Improve Yeasts' Brewing Properties

Many attempts have been made to design yeast strains with improved brewing properties. Strain improvement has been achieved using techniques known as mutagenesis and selection, hybridization and transformation. In mutation, random modification of the genetic code (DNA) occurs. Selection techniques are then used to find strains among the mutated population of yeast with more desirable brewing properties. For example, by using these techniques mutants with increased ability to utilize maltotriose have been selected. Hybridization takes advantage of the sexual cycle of yeasts by mating strains to combine desirable properties of the two parent strains in the offspring. With this technique, hybrids of *Saccharomyces cerevisiae* and *Saccharomyces diastaticus* have been developed with the favorable ability to ferment dextrins, resulting in higher attenuation. This is useful in the production of calorie-reduced (light) beers. The fusion of protoplasts (i.e., yeast cells with the cell wall removed) has allowed the transfer of the flocculation character from one strain of yeast to another. Transformation is another process by which DNA from one strain is introduced into another strain and becomes a stable part of the genetic material of the resultant cell.

Conclusion

Basic understanding and acceptance of the biology of yeast can provide the brewer with valuable insights when managing yeast in the fermentation process. There is no magic in selecting strains with the desired properties. It is no secret that yeast has to be properly nourished and employed at an optimal pitching rate.

Yeasts have been one of the instruments the brewer has used to orchestrate the production of beer over the centuries. With dedication and attention to detail in the use of ingredients, equipment and time in the overall brewing process, we have enjoyed an exciting explosion of beer varieties. Our increased understanding of yeast properties can only complement these dedicated and creative efforts in optimizing beer quality and production.

GEORGE FIX

Wild Yeast

For the most part, you want to keep these outlaws away from your civilized brews, but there are exceptions . . .

It is customary to classify microorganisms first by their genus and then by the species within a given genus. The genus *Saccharomyces* is the most important for fermented beverages, and in brewing the species *Saccharomyces cerevisiae* ("top yeast") and *Saccharomyces uvarum* ("bottom yeast") are the most widely used. While this classification is of scientific value, it does pose a number of problems as far as practical brewing is concerned. The point is that strains within a given species can vary significantly in brewing performance and in fact some can be quite "wild." On the other hand, yeast that is not from the brewing species can on occasion behave in an acceptable manner.

An interesting example of this is the so-called Whitbread culture. This actually consists of three strains, all of which are "wild." Strain No. 1 is a *Saccharomyces cerevisiae* mutant. It has lost its ability to flocculate and to ferment maltotriose. It also has a low ethanol tolerance and generally terminates metabolic activity in the middle of the fermentation. Strain No. 2 also is a *cerevisiae* mutant. It is a slow starter and will not flocculate. However, once active it is an exceptionally good fermenter.

The combination of Nos. 1 and 2 is a "marriage made in heaven," for once No. 1 stops, No. 2 starts up and completes the fermentation. The metabolic role of Strain No. 3 is uncertain, but there is evidence to suggest that it tends to curb No. 2's appetite for producing fermentation byproducts. The major role of Strain No. 3 is as a "chaining yeast." Once the fermented beer is chilled below 50 degrees F (10 degrees C) it heads toward the bottom of the fermenter, taking with it yeast cells in suspension (e.g., Nos. 1 and 2) as well as some high molecular weight proteins. This is definitely a culture where the whole is dramatically greater than the sum of its parts, and defies classification. While the individual strains are "wild," the whole is very much a brewing series that can be and has been used to produce interesting ales and beers.

In order to avoid paradoxical classification situations such as this, a functional approach will be taken. To wit, if it waddles like a duck and quacks like a duck, then a duck it shall be even if a biologist insists that a microscopic examination reveals it is better classified as cow!

To this end, a pure brewing yeast strain is defined as one where after respiration the following major pathway is followed:

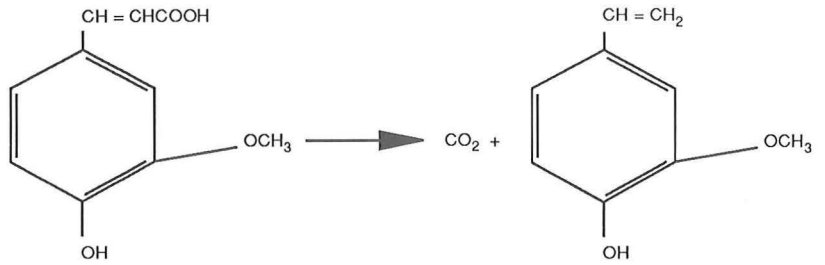
monosaccharides → pyruvic acid → acetaldehyde + CO_2 → ethanol + CO_2.

Thus, with a pure yeast strain, ethanol and carbon dioxide are the only fermentation products, and the flavor of the finished beer is determined by the ingredients used (e.g., malt and hops).

Other yeast strains will show a tendency for "divergences"; i.e., in addition to the major pathway there also will be "side streets" yielding other fermentation products. In this regard, the "wildness" of a yeast strain is taken as the extent to which the extra fermentation products will be noticeable in the finished beer. Bacteria are defined as those microorganisms where the major pathway is for all practical purposes not followed at all, and the minor "routes" are their major pathways.

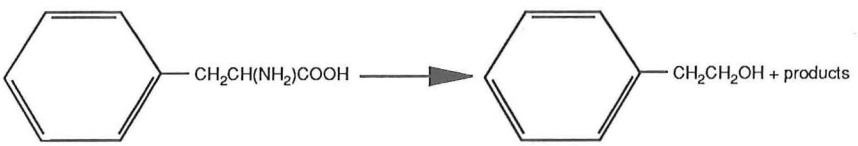
For this definition to make sense, some type of standardization is needed. For example, asking a pure yeast strain to ferment a wort of very high gravity at an elevated temperature will produce excessive ester levels even though the strain usually does not produce esters. For the purpose of this article a standard wort is taken as one made entirely of barley malt, having an original gravity of 1.048 (12 degrees P), and fermented at a temperature appropriate to the strain in question. The data presented in the sequel were derived from test fermentations of this standard wort.

The following characteristics are some of the major fermentation products that define the "wildness" of a particular yeast strain. No attempt will be made to assign degrees of "desirability" or "undesirability" to these constituents. That is a matter of subjective opinion, and individual brewers will come to their own conclusions about such matters. In fact, certain specialty beers depend on wild



Ferulic acid 4-vinyl guaiacol

Figure 1.



Phenyl alanine Phenyl alcohol

Figure 2.

yeast and their products to achieve a particular flavor profile. On the other hand, off-flavors produced by wild yeast infection cannot be ignored. Although they generally are not as distracting as those created by bacteria, they are far more common.

Phenolics. The most common feature among wild yeasts is their ability to create phenolic constituents. One mechanism is the conversion of mildly flavored phenolics from malt into stronger-flavored constituents. (See Figure 1.)

The product produced has a strong clovelike flavor profile and, for example, is an important part of Bavarian wheat beers.

A second mechanism involves fusel alcohols in beer. They arise from the metabolism of amino acids. Of interest to this category are the phenol alcohols (sometimes called aromatic alcohols), which have exceptionally strong medicinal flavors. A typical reaction is illustrated in Figure 2.

As a general rule, top yeasts produce more phenolics than bottom yeasts, yet preferences among strains is the major factor. Table 1 shows some examples. Currently Red Star brand yeast is a major phenol producer (a fact that constantly gets rediscovered by unsuspecting brewers), while Sierra Nevada is neutral. Whitbread also produces subthreshold phenolics; however, this constituent has been tasted by sensitive palates in beers made with this yeast. The data on the Spaten wheat beer yeast show that the clovelike flavor of Bavarian wheat beers is definitely a fermentation characteristic. Incidentally, reports show 4-vinyl-guaiacol levels in German wheat beers as much as 10 times higher than those produced by the Spaten strain in our standard wort. Thus it is apparently a rather neutral strain as far as wheat beer yeasts go.

The lager yeast was supplied to the author by Gary Bauer. It comes from Weihenstephan (number designation unknown). It is an excellent bottom yeast, and typically will not produce phenols.

It is important to note that wild yeast infection can dramatically change brewing performance. An extreme example of this was a liquid culture distributed to amateur brewers a few years back under the name "Amateur Brewer." Evidence suggests this yeast culture was contaminated by strains from *Saccharomyces diastaticus*. Typical of such infections, the result is a superattenuating yeast that produces considerable amounts of phenolics.

Closely related to the Amateur Brewer strain are the so-called "killer" yeasts. These are yeasts that excrete specialized enzymes during the fermentation, and are lethal to all other known microorganisms. Once present, they will quickly take over a culture. Considerable research has gone into genetically engineering these strains to retain the killer

Table 1. Phenolics

T = Flavor Threshold in ppm (parts per million)

Yeast Strain	Phenol Alcohol (T=100)	Guaiacol (T=0.3)
Saccharomyces cerevisiae		
Sierra Nevada	30	<.1
Whitbread	60	<.1
Spaten (wheat beer)	45	.4
Red Star Ale	130	.2 to .3
Saccharomyces uvarum		
Yeast Bank (G. Bauer)	35	<.1
Wild		
Amateur Brewer	151	.6
Killer Yeast (Canada)	156	.7
Montrachet (*Sacch. cerevisiae* var. *ellipsoideus*)	133	.2 to .3
Champagne (*Sacch. uvarum, Sacch. florentinuo*)	122	.2 to .3

factor, but at the same time brew normal beer. Progress has been made except for one point: All of these strains are prodigious phenol producers. The data in Table 1 show this clearly.

A good deal of evidence shows the most common type of wild yeast infection in brewing comes from wine yeast. In fact, an interesting theory conjectures that *Saccharomyces uvarum* made its entry into brewing by exactly this mechanism. Winemaking in Bavaria, now discontinued, started well before brewing. Strains of *Saccharomyces uvarum* are indigenous to selective vineyards (most notable is the Champagne district of France). Thus at the time winemaking and brewing were contiguous, it could have happened that the original brewing yeast (strains of *Saccharomyces cerevisiae*) became "contaminated" by the new yeast.

In general, wine yeast infection will not produce favorable results. A crucial point in this regard is that the amino acid composition of wine must differ dramatically from beer wort, and this is reflected in yeast performance. The worst possible way to impart a "winy flavor" to beer is to use wine yeast, and the data in Table 1 show that phenolics are a big part of this story.

Esters/Alcohols/Organic Acids. These three constituents come as a package with esters being the product of an acid plus an alcohol. Their formation is not spontaneous, and requires an agent (most notably yeast) to promote them. For this reason the author believes the following constituents and their accompanying flavors are excellent measures of "wildness" of a yeast strain. More data are given in Table 2.

Propyl alcohol
Butyl alcohol
Amyl alcohol
} Fusel alcohols (harsh, alcohol-like)

Ethyl acetate = ethanol + acetic acid (nail polish)

Amyl acetate = amyl alcohol + acetic acid (banana)

Table 2. Esters/Alcohols/Acids

(T = Threshold in ppm)

Strain	Propyl Alcohol (T = 600)	Butyl Alcohol (T = 25)	Amyl Alcohol (T = 110)	Ethyl Acetate (T = 35)	Amyl Acetate (T = 2)
Saccharomyces cerevisiae					
Sierra Nevada	15	20	70	26	2
Whitbread	28	59	138	36	8
Saccharomyces uvarum					
Yeast Bank	20	16	60	30	2
Wild					
Thomas Hardy	21	53	148	65	12
Montrachet	31	56	125	57	3
Champagne	20	51	115	52	3
Mutant Strain	39	57	132	41	4

The wild side of the Whitbread culture is seen clearly in Table 2. A consistent fingerprint of this yeast is its tendency to produce banana esters (e.g., amyl acetate) at levels three to four times their threshold. Such flavor tones are regarded as normal, and in fact desirable, for some traditional pale ales. In other beer styles they may be controversial. In contrast, the Sierra Nevada culture is entirely neutral in this area, as is Gary Bauer's bottom yeast.

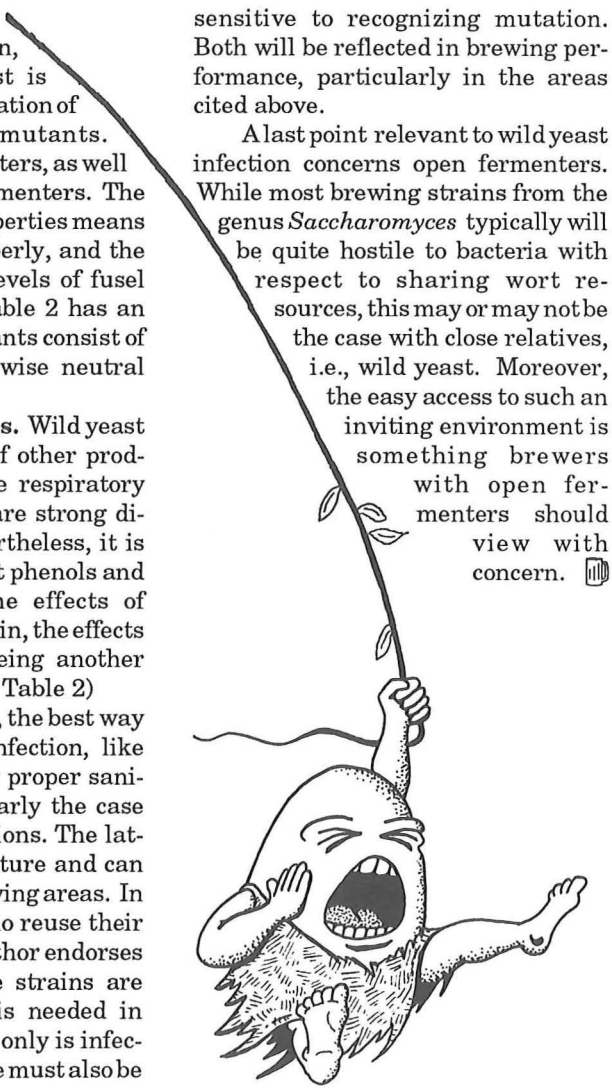
The Thomas Hardy yeast is yet another mixed culture used for strong ales and barley wines. The main strain is from the *Saccharomyces cerevisiae* species, and appears to be normal in all respects. The second strain is a member of the genus *Brettanomyces* (of unknown species). It is used to finish up the fermentation of high-gravity ales. Typical of slow-starting wild yeast, it is a strong ester producer. In most brewing situations, strains such as this one would be regarded as a contaminant, because the esters and fusel alcohols produced easily could overpower other beer constituents. The same is true for the "wine yeasts." When they ferment standard beer wort, not only are considerable amounts of phenols produced, but also large amounts of esters and fusels.

One way a neutral yeast strain can go wild, apart from outside infection, is by mutation. A common situation, particularly when yeast is being reused, is the formation of respiratory deficient mutants. They tend to be slow starters, as well as strong and rapid sedimenters. The absence of oxidative properties means they do not respire properly, and the net result is elevated levels of fusel alcohols and esters. Table 2 has an example where the mutants consist of 10 percent of an otherwise neutral yeast.

Other Mechanisms. Wild yeast can produce a variety of other products. For example, the respiratory deficient mutants also are strong diacetyl producers. Nevertheless, it is the author's opinion that phenols and esters best capture the effects of "wildness" in a yeast strain, the effects of bacterial infection being another matter altogether. (See Table 2)

In the final analysis, the best way to control wild yeast infection, like bacterial infection, is by proper sanitation. This is particularly the case with "wine yeast" infections. The latter are ubiquitous in nature and can easily gain access to brewing areas. In addition, for brewers who reuse their yeasts (a practice the author endorses particularly if desirable strains are obtained) special care is needed in their management. Not only is infection to be avoided, but one must also be sensitive to recognizing mutation. Both will be reflected in brewing performance, particularly in the areas cited above.

A last point relevant to wild yeast infection concerns open fermenters. While most brewing strains from the genus *Saccharomyces* typically will be quite hostile to bacteria with respect to sharing wort resources, this may or may not be the case with close relatives, i.e., wild yeast. Moreover, the easy access to such an inviting environment is something brewers with open fermenters should view with concern.



PAUL MONK

Yeast Nutrients in Brewing

Can you improve your yeast's performance with some nutritious additions to your wort? It's possible, but yeast can be finicky.

Yeasts are facultative microorganisms that are able to grow both aerobically and anaerobically by obtaining energy from catabolism of certain carbohydrates. The available energy is coupled to the anabolic process of the cell, fabricating essential cell components from intermediates of carbohydrate and nitrogen metabolism and other nutrients provided in the growth medium.

Strains of brewing yeast, while growing in wort, have two main functions: to convert sugars to alcohol and contribute desirable sensory compounds to beer under essentially anaerobic conditions. To grow successfully in wort the yeast culture must be provided with many essential nutrients, both macro and micro molecules. The availability and concentration of nutrients in wort depends upon the grain, malting procedure and water.

The nutrients required for yeast growth can be broadly grouped as carbohydrates, nitrogen (both organic and inorganic), vitamins, minerals and molecular oxygen.

Carbohydrates

The sugars in wort that are available for yeast growth are, in order of concentration: maltose, maltriose, glucose, sucrose and fructose. The total fermentable sugar in wort ranges between 7.5 and 9.5 grams per liter. Sugar is not limiting to yeast growth in wort; however, uptake of sucrose is dependent upon extracellular invertase to hydrolyze it to glucose and fructose. Unadapted yeast cells require an induction time to ferment maltose.

The metabolism of sugars in wort is by fermentation even in the presence of oxygen. Glucose in excess of about 2 grams per liter inhibits respiration by a process called catabolic repression, also known as the Crabtree Effect.

Another significant contribution of carbohydrate metabolism, in addition to providing energy for yeast growth, is the accumulation of the polysaccharides trehalose and glycogen. These compounds increase in the cell as yeast growth slows and continue to be stored, increasing cell biomass, after the cell has stopped budding. Nutrient limitation in wort, particularly limitation of available nitrogen, will stimulate the accumulation of trehalose and glycogen.

These compounds act as reserve materials, being metabolized in the resting cell to provide both energy and carbon for maintenance and to retain viability during storage.

When yeast is pitched into wort to initiate a new fermentation, the yeast biomass is found to decrease during the lag phase. The loss in mass is attributed to glycogen metabolism, which is accompanied by an increase in sterol content and removal of dissolved oxygen from wort. Slow and incomplete wort fermentations have been attributed to inadequate concentrations of cell glycogen caused by previous growth or storage conditions.

Nitrogen

The concentration and type of available nitrogen in wort determines the rate of fermentation, the amount of yeast growth and the sensory properties of the finished beer. The metabolism of nitrogen by a particular yeast strain is of major importance in all alcoholic fermentations.

Nitrogen is available for yeast growth in wort as inorganic nitrogen, amino acids and peptides. The nitrogenous compounds in wort depend upon the grain used and the malting and mashing process. Hopped wort contains an average of 800 milligrams per liter of total nitrogen, one-half of which is alpha-amino nitrogen. After fermentation the beer contains an average of 200 milligrams alpha-amino nitrogen per liter, some net 200 grams per liter being incorporated into yeast cell protein or sensory compounds. The fate of amino acids taken up by the yeast cell is complex. Very little, if any, of an amino acid in wort is incorporated intact into cellular protein. Instead, it undergoes a transamination reaction leading to products of glutamic acid and a corresponding oxoacid. The oxoacids formed by yeast act as substrates for the biosynthesis of aldehydes and fusel alcohols that significantly influence the sensory properties of beer. The formation of esters also is related

to amino acid metabolism, providing alcohols to react with fatty acids made available during the synthesis of saturated and unsaturated fats and phospholipids.

Brewing yeast can grow on a medium containing an ammonium salt (another form of nitrogen nutrient) more rapidly than on any individual amino acid. However, a mixture of amino acids, as found in wort, supports better growth. Wort contains about 24 milligrams ammonia per liter and only a small amount is utilized for yeast growth where amino acids are not growth limiting.

The concentration of alpha-amino nitrogen or ammonium salt is directly related to the fermentation time for a wort; that is, the higher the concentration of available nitrogen, the faster the fermentation. Amino acids and ammonium ions are taken up by active transport systems involving many different permeases (carriers); however, concentrations in excess of that required to supply nitrogen for growth stimulate yeast growth rate. From a practical viewpoint, the nitrogen nutrient supply, either from malt or addition of ammonium salt, can determine yeast growth, fermentation time and the sensory properties of a beer. Different yeast strains under similar conditions have different growth rates, nutrient requirements and abilities to produce and excrete esters and fusel alcohols. The interaction between yeast strain and wort composition can determine beer quality and style.

Minerals

On a dry weight basis, yeast contains an average of 2.6 percent phosphate as P_2O_5, 2.5 percent potassium as potassium dioxide (K_2O), 0.4 percent magnesium as magnesium oxide (MgO), 0.5 percent sulfur and trace amounts of calcium, chlorine, copper, iron, zinc and manganese. The relative proportions of these compounds in yeast give an indication of their importance to yeast metabolism.

Yeasts are unable to grow unless provided with a source of phosphate. This anion is involved in energy conservation and transfer and is part of many organic compounds in the yeast cell. Yeast actively transports phosphate as the monovalent anion $H_2PO_4^-$. The transport and incorporation is very rapid and the concentration gradient high. Inorganic phosphate is stored as metaphosphate in the cell, part of which can be converted to orthophosphate when required. The presence of stored metaphosphate is considered necessary for rapid yeast growth, providing a source of phosphate and acting as a reserve of chemical energy to drive metabolic reactions. Phosphate provided to wort from malt is usually adequate for growth; however, some stimulation can be observed by increasing the phosphate concentration. Potassium is required for yeast growth and fermentation although it is not incorporated in the structural or organic components of the cell. Potassium ions are taken up by active transport, which requires energy. As yeast assimilates glucose, potassium ions are taken up simultaneously and are accompanied by the transfer of a hydrogen ion. The permease or carrier that transports the K^+ into the cell also transports NH_4^+, but with a much lower affinity.

Potassium ions are necessary for the uptake of phosphate. Phosphate uptake leads to acidification of the cell, which then retards phosphate transport. The simultaneous uptake of the K^+ ion increases the buffer capacity of the cell, allowing accumulation of higher phosphate concentrations. Wort contains adequate amounts of K^+ ion for operation of transport systems and active yeast growth.

Magnesium is required for yeast growth and acts as an enzyme activator, particularly for phosphate transferases and decarboxylases; for example, pyruvate decarboxylase, which yields acetaldehyde. Magnesium is actively transported into the cell, accompanied by the secretion of two K^+ ions. K^+ ions at low concentrations stimulate the uptake of the Mg^+ ion, but at high concentrations limit its uptake.

Yeast requires sulfur for the synthesis of methionine and cysteine, which are incorporated into protein, glutathione, coenzyme A and thiamin. Biotin also contains sulfur but brewing yeast is unable to synthesize this vitamin.

In wort, sulfur is available to yeast as inorganic sulfate, methionine and in soluble proteins and peptides. Sulfate is metabolized by yeast, first being converted to sulfite and then sulfide before being used in the formation of the end products methionine and cysteine. The hydrogen sulfide formed from metabolism of sulfate can be excreted into wort if the yeast becomes starved for nitrogen due to either low concentration in the medium or impaired ability to transport available nitrogen into the cell.

The elements zinc, copper and manganese are required in trace amounts and promote the rate of fermentation. In high concentrations they are toxic and, while addition of zinc to wort can be beneficial, manganese must be present to avoid autolysis and inhibition of growth.

Vitamins

Vitamins are essential cofactors of enzyme function and are required for yeast growth. Requirements for vitamins by yeast are strain dependent and their addition to wort can often stimulate yeast growth rate and fermentation.

Biotin. Biotin cannot be synthesized by brewer's yeast and must be available in wort. Biotin is involved in carboxylation of pyruvic acid, nucleic synthesis, protein synthesis and synthesis of fatty acids, and hence plays a central role in yeast metabolism. Yeasts starved of biotin have a high death rate caused by inhibition of deoxyribonucleic acid synthesis. Damage to the cell membrane results from a deficiency in fatty acid. Biotin is required in very low concentrations,

5 milligrams per liter being adequate to support yeast growth.

Pantothenic Acid. Pantothenic acid is required by many strains of fermentation yeast and is an essential part of coenzyme A, required for carbohydrate and lipid metabolism and cell membrane function. A deficiency of pantothenate can lead to the accumulation of hydrogen sulfide and will occur when pantothenate concentrations in the medium fall below 0.15 milligrams per liter. Stimulation to yeast growth rate and yield is dependent upon pantothenate concentration, but does not affect yield of ethanol from carbohydrate.

Thiamin. Thiamin as thiamin diphosphate is the coenzyme in oxoacid decarboxylation. Thiamin will stimulate the growth rate and hence fermentation of brewing yeast but will not necessarily increase cell yield. A few strains are unable to synthesize thiamin. Top-fermenting yeast requires either thiamin or pyridoxine while bottom-fermenting yeast can grow well without the addition of either vitamin to the medium. When added to a medium the yeast rapidly accumulates thiamin. Thiamin added to medium in which *Saccharomyces uvarum* is growing is found to interfere with the synthesis of pyridoxine, requiring the addition of pyridoxine to the growth medium.

Nicotinic Acid. Nicotinic acid is required for the synthesis of NAD and NADP coenzymes that act in conjunction with dehydrogenases. Brewing yeast can synthesize its requirements for nicotinic acid under aerobic conditions, but this ability is restricted in the absence of oxygen.

Inositol. Inositol is required for cell division. When combined with lipids it is used for cell structure. A deficiency will decrease the rate of carbohydrate metabolism. Brewing yeasts vary in their ability to fulfill their own requirements for inositol and many yeasts show stimulated growth rate and yield when it is available in the medium.

Oxygen

Dissolved oxygen can be considered a yeast nutrient. The availability of oxygen to a yeast culture will determine initiation of fermentation and its completion. Molecular oxygen provided to a yeast culture is used to synthesize unsaturated fatty acids and sterols. These compounds are found mainly in the cell membrane and are required for activity of membrane-bound enzymes, permeability and alcohol tolerance. Squalene formed anaerobically in the cell is the precursor to the oxygen-requiring reactions leading to lanosterol, ergosterol and zymosterol.

Yeast growth without oxygen causes dilution of sterols in the cell membranes as a result of distribution between cells at division; there is a critical concentration of these compounds in the cell below which cell division does not occur. It is estimated that five generations are the maximum that can be achieved by yeast initially provided with unsaturated fatty acids and sterols.

A yeast starter culture can be provided with adequate membrane lipids when grown with aeration prior to pitching or from aerating the wort when a portion of the brewing yeast is repitched. Aeration of wort is not necessary for properly prepared starter culture or dried yeast.

The transfer of oxygen into wort is dependent upon temperature, sugar concentration and air dispersion. To maximize yeast yield, the wort should be 25 to 50 percent saturated with oxygen prior to pitching the yeast.

Overview

The membrane of a yeast cell separates the cytoplasm and enclosed organelles from the fermentation medium, and by selective transport in and out of the cell maintains an environment suitable for metabolism and growth.

The ability of a yeast culture to grow in wort and complete fermentation depends upon the condition of the cell membrane, the availability, concentration and relative proportions of nutrients, the viable cell density on pitching and the fermentation temperature. The brewer can manipulate the conditions of fermentation to ensure the production of a quality beer.

The conditions of the cell membrane can be optimized by aerobic preparation of a starter culture, efficient aeration of wort prior to or after pitching, or use of active dried yeast. In wort the availability of nitrogen as amino acids can be a growth-limiting factor and can be supplemented where necessary with inorganic nitrogen as diammonium phosphate. Low growth rate or cell yield resulting from vitamin deficiencies, which can lead to slow or incomplete fermentations, can be treated by adding a vitamin supplement at the time of inoculation. The supplement, when required, should include biotin, pantothenic acid, inositol, pyridoxine and thiamin.

The ability of a yeast strain to grow at the low temperatures used in lager fermentations is yeast-strain dependent and for a given strain might require a period of adaptation. Yeast grown at low temperatures contains higher concentrations of fatty acid in the cell membrane. These concentrations improve the ability to transport nutrients.

CLAYTON CONE

Commercial Production of Dried Yeast

Yeast and fermentation have been a part of daily life at least since 4000 B.C., when the Egyptians were eating leavened bread. Wine and beer were also a food staple during this period, so much so that the Romans planted vines wherever they went, ensuring that the resident governors had an adequate supply of wine.

Until the mid-19th century, yeast fermentation was not understood. Bread was made from a "sour-dough" process, where the baker would keep small amounts of the yeast-infected dough with which to inoculate the next day's bread. Primitive alcoholic fermentations were left to occur spontaneously. Wine, mead, beer and subsequent distilled beverages also were left to spontaneous fermentation.

During the early 19th century, byproducts of the breweries, and later the distilleries, were used to ferment bread dough. As the bakeries became larger, distilleries found an increased market for their byproducts. The subsequent work of Louis Pasteur and E.C. Hansen (Hansen isolated the first single-cell yeast culture) explained the role of yeast in fermentation and the importance of pure culture fermentations. By the close of the century several firms were producing modest amounts of pure yeast from aerated grain mashes.

As the availability and cost of grains became a deterring factor, a scientist by the name of Hayduck in Berlin developed a method for producing yeast from molasses fortified with ammonium salts and phosphates. Subsequent research improved the yeast metabolism of sugar to cell matter, while still avoiding alcohol production. This is accomplished through high aeration with gradual nutrient feed. The industry today still employs this process, tailored to exploit the new strains being used. Research during the last 30 years has focused on improving yeast strains and automation of the fermentation process, along with improved refrigeration, packaging and drying techniques.

The preparation of yeast in dry form dates back many centuries. Yeast was being successfully dried long before anyone had any idea what was being dried. Bakers back in the Roman days held elevated positions akin to that of priests because of their abilities to make this magical, mystical substance turn dough into leavened bread. Along with this lofty position came an awesome responsibility. Bread was the basis of the diet and the Roman army depended on a steady supply. Thus, if the baker lost the yeast culture he often lost something more important to him—his life. With an incentive like this, it was not long before bakers found that they could spread a yeast-containing slurry onto wheat hulls or gypsum blocks and place it in a sunny spot to dry. When needed, they mixed the dried material with a sweet liquid and it would come to life again. Variations on this old Roman technique are used even in present times.

Dried yeast has an ancient history, but here's a look at current techniques for making it.

The production of active dry yeast began on a massive scale during the early 1940s. At this time, the U.S. government gave large grants to companies such as Fleischmanns to develop techniques that would produce large volumes of yeast that could be shipped without refrigeration to the armed forces.

The initial drying machines were tunnels. Compressed yeast with about 70 percent moisture is extruded in spaghettilike form onto a perforated steel belt and slowly passed through a tunnel containing several chambers. The temperature, humidity and air flow are carefully regulated in each chamber to evaporate and draw moisture from within the yeast cell at a predetermined rate that will ensure maximum viability and activity. The yeast leaves the last chamber with a 7 to 9 percent moisture content. This process takes three to five hours and sometimes longer.

Recent improvements have been made in drying technology and we

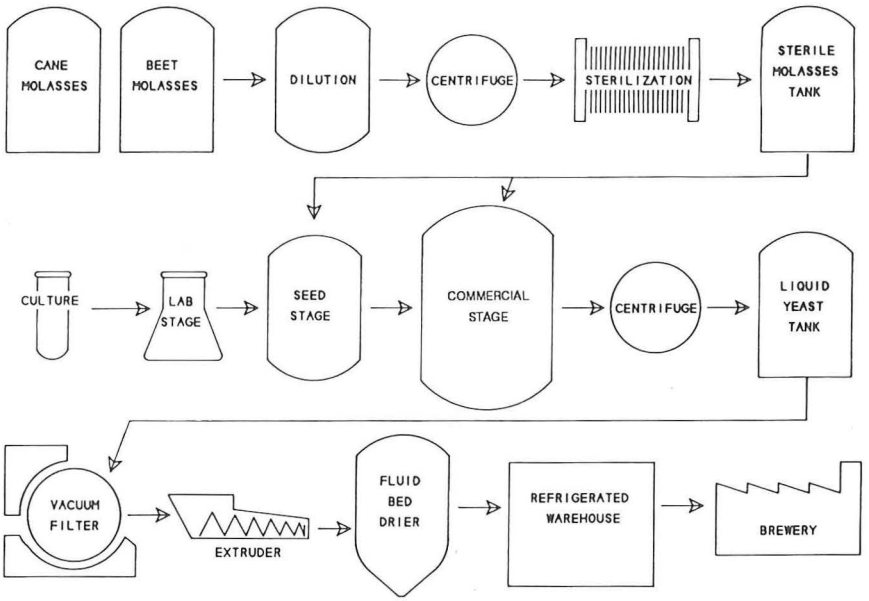


ILLUSTRATION COURTESY OF LALLEMAND

Figure 1.

Commercial yeast production flow chart.

have a better understanding of the yeast during drying. Currently most yeast is dried in a fluid-bed drier. Compressed yeast is extruded, in threads about the size of a .5 mm pencil lead, onto a perforated plate in a single chamber. The yeast is air-lifted with carefully controlled flow, temperature and dehumidified air, allowing it to dry to 4 percent moisture in about one-half hour. This rapid and controlled drying captures almost all of the viability and activity of the original yeast.

The yeast from both types of driers is quickly cooled and packaged in an inert atmosphere of nitrogen and carbon dioxide or in a vacuum to give it long-term stability. At 40 degrees F (4.44 degrees C), it will retain 96 percent of its activity after one year. At 68 degrees F (20 degrees C), it will retain 80 percent of its original activity during the same period.

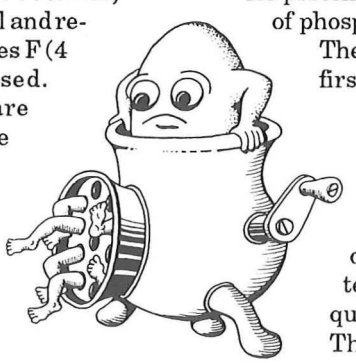
Yeast strains for the brewing industry are selected by brewing institutes or breweries. These strains usually have a long history of performing and of producing for the brewmaster exactly what he requires for his equipment and particular style of beer. The culture is submitted to the yeast manufacturer to be produced on an industrial scale. The research laboratory will study its growth patterns and requirements, and produce a small amount in dry form. The brewing institute or brewery will compare the performance of the yeast in dry form against the original slant of yeast brought up in the traditional manner. If the performance of the dry yeast is equal to or better than the liquid yeast, plant-scale production will begin.

The strain is now typed and fingerprinted. The DNA is mapped and recorded for future reference to be certain that no contamination of the original strain occurs and that any mutations do not go unnoticed and later alter the fermentation characteristics. The culture is then streaked onto numerous special nutrient agar slants, allowed to grow at 86 degrees F (30 degrees C) for 24 to 36 hours, placed under sterile oil and refrigerated at 39 degrees F (4 degrees C) until used. Numerous slants are made to eliminate the need to inoculate from a single slant more than one time, thus minimizing the chance of introducing infection at this early stage.

The quality of the yeast begins at the test tube stage in the laboratory, and each subsequent stage is carefully controlled so that the yeast performs exactly as the customer demands. Figure 1 shows the general flow of production from test tube through the drier.

The commercial production of yeast is accomplished by aerobic fermentation, which is fermentation stimulated by the introduction of air. Aerobic fermentation results in more efficient yeast growth. In most other industrial fermentation, such as brewing, the fermentation is anaerobic (without air) and it is the byproducts (alcohol, esters, higher alcohols and carbon dioxide) that are desired instead of the yeast itself.

To start the aerobic fermentation process, a small inoculum of pure culture is transferred to a flask containing six liters of a sterile culture medium. For this and subsequent stages, the basal medium is a sterilized solution of cane and beet molasses, treated and called "wort." In addition to the wort, the yeast is supplied with essential nutrients and microelements needed for optimum cell growth. Yeast is unique in that it can utilize ammonia as a sole source of nitrogen for protein production, with the aid of phosphoric acid.



The laboratory stage and the first stage in the plant are carried out aseptically with minimum aeration. It is essential in the early stages to build up a cell mass free of infection. Careful attention to sanitation is required to achieve this goal. The wort is sterilized at

290 degrees F (143 degrees C) for 20 seconds. All equipment — tanks, lines, pumps, heat exchangers and separators — are chemically cleaned and steam sterilized before each use.

The essential element of economic yeast production is the production of cell mass without the production of alcohol. The first prerequisite is aeration, the second is the gradual addition of wort. It is vital to feed only as much wort as is required by the yeast cell. An excess of more than 0.05 percent at any time will trigger the yeast to produce alcohol.

The growth that occurs from the initial flask to the fourth and sometimes fifth stage is known as the seed production stages. Each stage, once finished, is transferred to the next larger stage. With this technique, less than one gram of yeast will produce more than several tons in four or five steps and a total fermentation time of 72 to 96 hours. At the end of the fourth or fifth stage the fermentation liquid is centrifuged and washed several times to separate the yeast from the "spent" wort. This step allows efficient handling of the used yeast to inoculate the last or commercial stage. The separated yeast, suspended in water, is held in refrigerated storage tanks at 39 degrees F (4 degrees C).

It is during the final commercial stage that careful attention is given to controlled growth rates and nutrients in order to produce a yeast with optimum protein, phosphate, glycogen, trehalose, lipid, vitamin and enzyme levels to assist the yeast through the drying stage and provide the brewmaster with a yeast of optimum activity. At the end of this stage the yeast is separated and washed several times and stored in refrigerated tanks (receivers) prior to drying.

The liquid yeast is dehydrated to about 30 percent solids with a "rotary vacuum filter." The "cake" or compressed yeast is extruded in thin spaghettilike filaments onto a special fluid-bed, air-lift drier where a controlled drying sequence yields a finished dry yeast with 4 to 7 percent moisture. The yeast is cooled and stored immediately in an inert atmosphere until it is packaged in five-gram and 500-gram nitrogen-filled packages and one-kilogram, 10-kilogram and 20-kilogram nitrogen-filled or vacuum packages.

There are 20 to 40 billion yeast cells per gram of active dry yeast. This wide range is caused by the variation in cell size of different strains of yeast. Approximately 85 to 90 percent of the cells retain their viability during the drying stage. Each live cell retains 100 percent of its activity when properly rehydrated in water at 105 degrees F (40.5 degrees C).

Utmost vigilance is given to each stage of fermentation. The laboratory is involved with microbiological, biochemical and fermentation analysis to ensure the production of a uniform yeast with respect to composition, fermentation activity, viability, stability and purity of strain.

A yeast manufacturer knows that quality control does not end at the shipping dock. Utmost care must be given to keeping the yeast cool from the time it leaves the plant until it is inoculated into the customer's wort. Yeast in dry form is relatively inactive, but not inert. It will be adversely affected if supply houses and the customers handle it poorly. A little precaution regarding refrigeration of the finished product is warranted.

The increasing interest of homebrewers, microbrewers and consumers in quality and variety of beer styles has caused many yeast manufacturers to provide this market with a better and wider choice of yeast strains. Greater stress is being placed on providing information regarding proper storage and rehydration practices. The yeast packages should always be stored in a cool or cold place. The inventory should be rotated in such a way that the oldest yeast is used first. One of the attractive features of using yeast in the dry form is the ease in preparing the inoculum to add to the wort. Sprinkle the dry yeast slowly into 100 to 105 degrees F (40 to 40.5 degrees C) water while stirring slowly. Allow to stand 15 to 30 minutes. Bring the temperature of the rehydrated yeast close to that of the temperature of the wort. Avoid subjecting the yeast to abrupt cold temperatures. Add the yeast to the wort, which contains lots of oxygen and nutrients for the yeast. Now sit back and wait for good things to happen!

PAUL FARNSWORTH

Yeast Stock Maintenance and Starter Culture Production

Having problems with slow starts or contamination of your yeast? This quick course in home-culturing could take you a long way toward better beer.

To make clean beer, you must add at least one cup of actively growing yeast to your wort as soon as it is cool. The yeast then quickly takes over the whole five gallons and suppresses any other "bugs." Commercial yeasts may be contaminated or are available in such small volumes that they will not add enough to protect five gallons.

The only answer is to make your own cultures. One way of doing this is to store pure yeast strains and turn these into starter cultures to pitch into the wort. Once you have prepared slants and plates you can store them for many months. Routinely you only have to do steps (5), (6) and (7) (see overview). If your last petri dish of working culture is contaminated you need to repeat step (4). Here is a simple general scheme for yeast management.

Equipment and Supplies
(see Figure 1)

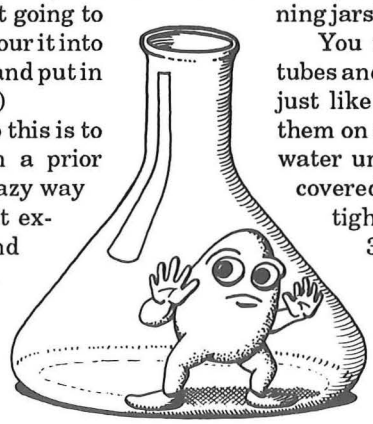
- 1 small (250 ml) conical flask with cap
- 1 large (1000 ml) conical flask with either a screw cap or a plug made from cotton wrapped in gauze
- small test tubes with caps and rack
- petri dishes
- inoculating loop
- aluminum foil
- electrician's tape
- agar
- dry malt extract
- A source of open flame: gas burner, portable stove, propane torch or mini welding torch
- pressure cooker or a large boiling pot (not shown)

Culture Preparation

1. Make Wort

Add eight rounded tablespoons of dry malt extract, or 10 tablespoons of syrup to 2 1/2 cups of water. Boil, covered, for 20 minutes and let cool. Pour off the liquid from the junk in the bottom. If you are not going to use it straight away, pour it into sanitized bottles, cap and put in fridge. (See Figure 2.)

An easy way to do this is to save some wort from a prior brew. An extremely lazy way is to dissolve the malt extract in hot water and not boil and cool it. This will work but will look ugly because when you sterilize it later on, you will get brown clumps of trub that look nasty but do no harm.



2. Make Solidified Wort

This is just like making Jell-O. When stirred into boiling liquid the dry agar powder will dissolve. When it cools it sets into a solid.

Add two rounded tablespoons of powdered agar to 2 1/2 cups of boiling wort and stir till dissolved.

If you are making slants, pour the mixture into each tube so they are one-third full and cap loosely. If you are making plates pour the mixture into two small jars, (baby food jars or canning jars) and put lids on loosely.

You must now sterilize the tubes and jars of mixture. This is just like home canning. Stand them on a rack in a pan and add water until they are about half covered. Boil for 20 minutes, tighten lids and let cool for 30 minutes. An even better idea is to use a pressure cooker. Cook for 10 minutes and leave to cool for 30 minutes. When the

tubes are almost too hot to touch you must do the next step quickly, before the agar sets.

If you are making slants, tighten the tube caps and tilt all the tubes at a 60-degree angle, prop them up and let them set. (See Figure 3.) If you are making petri plates put the sterile dishes out, unopened, in a row along the edge of a bleach- or alcohol-cleaned kitchen counter. Take one of the small jars of hot agar/wort mixture in one hand. With the other hand lift the lid of one of the petri plates just far enough to pour in the mixture. Add enough to half fill the dish. Replace the lid and go on to the next dish.

Work quickly, leave the lids open for as short a time as possible, leave the jar in your other hand tilted over all the time so you don't slop it about a lot and do not stop until you have run out of mixture or burned your fingers. Two cups of mixture should make 20 plates or 40 or more tubes, so don't worry, you will have plenty. Any leftovers can be stored in the jar in the fridge for next time.

Leave the plates and tubes at room temperature for five days. If they are contaminated you will see things growing. Anything that shows any change should be discarded. Those that pass inspection should be sealed with electrician's tape and stored in the cold. I know this all sounds like a pain but you only have to do it occasionally!

Master Culture

You must start with a clean, pure culture of yeast. You can buy these from the author (see address at end of article). You may also purchase them from J.E. Siebel & Sons in Chicago. Alternative sources are to beg some from a brewery, steal some from the sediment in a bottle-conditioned commercial beer or culture your own from one of the dried or liquid yeasts available commercially. If you use one of these sources, you must first plate out the yeast onto solidified wort to check for purity and then brew a batch of beer with it to make sure you have what you think you have. If the beer is good, use the culture on solidified wort to make your master culture.

Yeast Management Overview

Culture Preparation	1. Make Wort
	2. Make Solidified Wort
Master Culture	3. Inoculate Some Slants for Storage
Working Culture	4. Inoculate from a Slant to a Petri Plate
Starter Preparation	5. Make Flasks of Sterile Wort
	6. Make a Small Starter Culture
	7. Make a Large Starter Culture

3. Inoculate Some Slants for Storage

Light the flame of your gas stove, torch or burner. Hold the tube with the yeast, and a new slant tube of solidified wort, both in your left hand and with the tops pointed away from you and spread a couple of inches apart. Hold the loop in your right hand. (See Figure 4.) Loosen but do not remove the tube caps. Heat the loop till it is glowing red and hold it in your right hand like a pen.

Figure 1. Equipment required

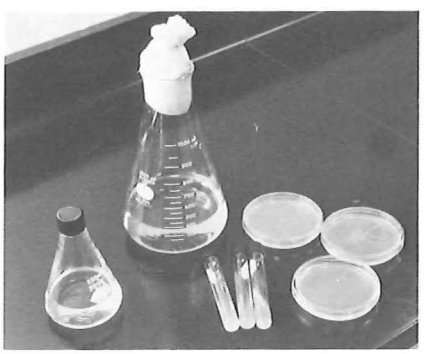


Figure 2. Liquid and solid wort.

With the crook of your little finger remove the cap from the yeast tube, pass the neck of the tube through the flame twice, then poke the loop into the tube and scrape up a little of the yeast—not much, there are billions of cells and you only need a few! Withdraw the loop and pass the neck of the tube through the flame twice, then recap it. Uncap the second tube, pass the neck twice through the flame, squiggle the loop carrying the yeast onto the surface of the agar in the "slant" tube, then flame the tube neck and replace the cap.

Put the tubes down and heat the loop to sterilize it. Work quickly, leaving the tubes open for the minimum time. This idea of holding both tubes in one hand and removing the cap with the little finger of the other hand, though it feels awkward at first, will speed things up.

Inoculate several slants and leave them at room temperature for five days. If the surface is covered with smooth pale cream or white yeast, label, seal and store the tubes in the cold. If it looks weird dump it and try again.

Working Culture

4. Inoculate from a Slant to a Petri Plate

Light your flame.

Hold slant tube of yeast in your left hand, the loop like a pen in your right hand, and place a plate of solidified wort, unopened, in front of you. Loosen but do not remove the tube cap.

Heat the loop till it's red. Remove the tube cap in the crook of your little finger, pressing it against your palm. Pass the tube neck twice through the flame, then put the loop into the tube and scrape up a little of the yeast. Withdraw the loop, pass the tube neck twice through the flame and replace the cap.

Lift the petri plate lid halfway and squiggle the loop over the plate surface. Replace the lid. Resterilize your loop. Leave the plate in the warm for four or five days. You should see white or cream-colored dots up to one-quarter-inch across (usually about one-eighth inch). They should all look the same. It's OK if they are fused together into a streak, but next time pick up a little less on the loop. If the dots, which are colonies of yeast cells, are colored or there is a hairy or cottonlike growth on the plate, discard it — it is contaminated. (See Figure 5.) If it's good, seal it with tape and store in the cold.

Starter Preparation

5. Make Flasks of Sterile Wort

Dissolve eight rounded tablespoons of dry malt extract in 21/2 cups of water and boil, covered, for 20 minutes, cool and pour the liquid off the sediment.

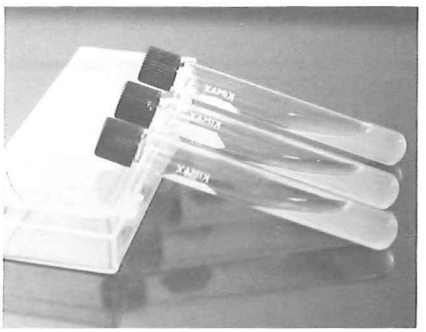


Figure 3. Tubes of molten wort.

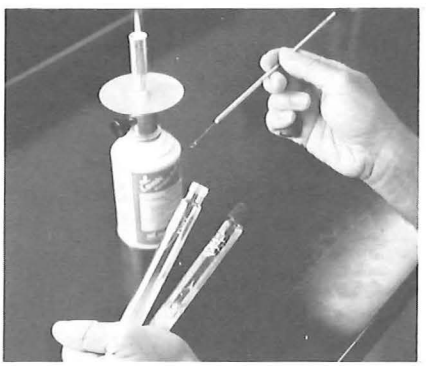


Figure 4. Transferring yeast from an old slant to a new slant.

Put about one-quarter cup into the small flask (up to the 75 ml mark), and two cups (up to the 500 ml mark) into the large flask. Cap them loosely and sterilize them, as you would for home canning. Put the flasks on a rack in a pot and add water, boil for 20 minutes, tighten the caps and let cool. Alternatively pressure cook them for 10 minutes and let them cool in the cooker. Store in the cold.

6. Make a Small Starter Culture

Three days before brew time you need a petri plate of yeast and two flasks of sterile wort. Take the small flask of wort, the petri plate, and your inoculating loop to the burner.

Heat the loop till red hot, open the plate lid halfway and touch the loop to the surface of the agar. You will hear a "pssst" as the loop cools. Now pick up one of the nice smooth-looking colonies with the loop, and close the dish lid. (See Figure 6.) This dish can be reused until it has visible contamination.

Keeping the loop in your right hand held like a pen, pick up the flask with your left. Remove the cap using the crook of the little finger on your right hand pressing it against your palm. Pass the flask neck through the flame. Then put the end of the loop into the juice in the flask and shake it to dislodge the yeast. Don't worry about getting it all in there, there are millions of cells in a loopful and you only need a few. Withdraw the loop, pass the flask neck through the flame and replace the cap.

Leave the flask in the warm for two days until the wort has become opaque. It's a sign you have waited too long when the yeast begins to settle down the the bottom.

7. Make a Large Starter Culture

Though this is the simplest step (you simply pour the contents of the small flask into the large flask of sterile wort) it is the most prone to contamination so you must do the flame-passing ritual again.

Hold the small flask toward the base in your right hand and remove the cap with your left. Put the cap down. Pick up the large flask in your left hand and remove its stopper using the crook of your little finger. Do not let the end of the stopper that goes in the flask touch anything, especially you. Pass the necks of both the large and small flasks through the flame several times each, twisting them as you do so, to heat at least half of the circumference. Then pour the contents of the small flask into the large flask, trying not to get any juice on the inside neck of the large flask. Pass the large flask neck through the flame twice and replace the stopper.

Leave the large flask in the warm

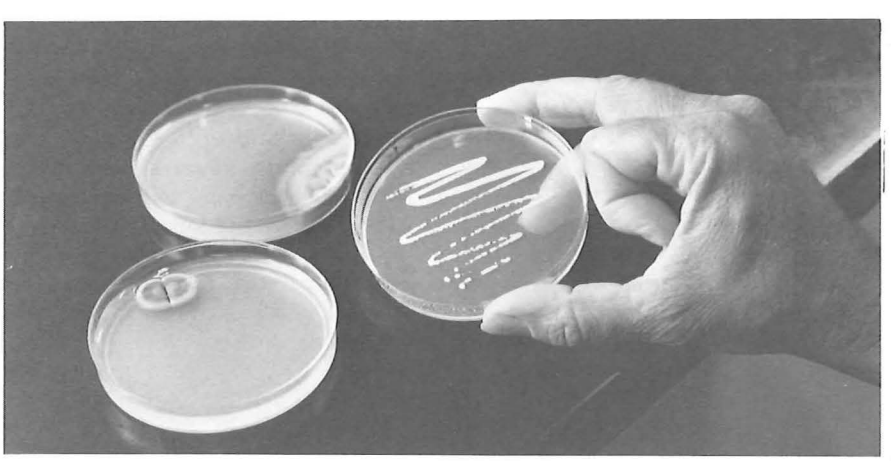


Figure 5. Petri dish with yeast growing in it (in hand) and two showing contiminants.

Figure 6. Picking colonies from a culture on a petri plate.

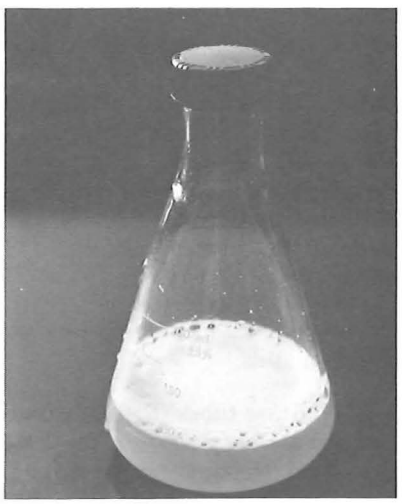


Figure 7. Starter culture at optimum growth stage for transfer.

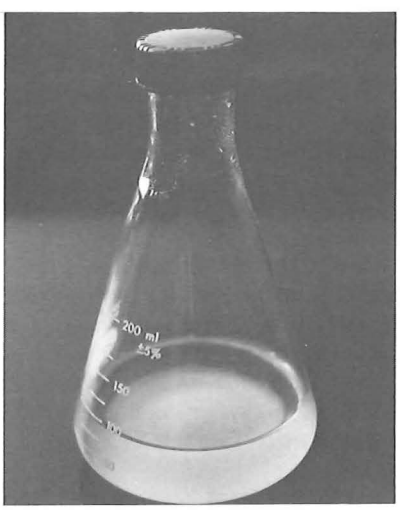


Figure 8. Starter culture past its peak, yeast has settled. Make a new culture before using.

until the wort is opaque. A head may rise and the culture is at its optimum when this just begins to fall. It is past its prime but still usable as the yeast begins to settle out. (See Figures 7 and 8.) You cannot store it in the cold and have it work correctly because the yeast cells will begin to die. If you do forget and put it in the refrigerator, take one-quarter cup of the mixture and use it as the small starter culture.

"Feeding" the yeast in an old culture by adding sugar or malt is not a good idea. This greatly increases the risk of infection. You also will be feeding any bacteria that are already present. Instead, you should prepare another flask with two cups of sterile wort and add one-quarter cup from the old culture to this new culture flask and then wait for 24 hours for the new one to grow up.

The author will supply pure yeast cultures and all the equipment and supplies mentioned in this article. For more information contact:

Dr. Paul Farnsworth
Scientific Service
7407 Hummingbird Hill
San Antonio, Texas
78255

A Quick Review of Culturing Yeast

Master Culture
Kept on solidified wort in sealed tubes ("slants") in fridge
Stock culture of pure yeast that you rarely use so it stays pure.

▼

Working Culture
Kept on solidified wort in petri dishes sealed and stored in fridge
Cultured yeast spread out so you can see whether it is pure. Used routinely to make starter cultures.

▼

Small Starter Culture
One colony of yeast transferred to 1/4 cup of sterile wort in a flask
Yeasts grown 36 to 48 hours initially in a small volume of liquid until they are healthy enough to dominate a large volume.

▼

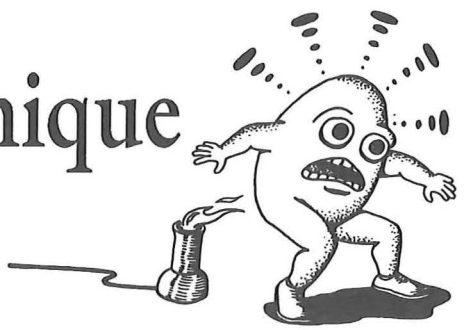
Large Starter Culture
Contents of small flask transferred to 2 cups of sterile wort in large flask
Yeasts grown for 24 hours in large enough quantity to start 5 gallons.

▼

Fermenter
Contents of large flask added to 5 gallons as soon as wort is below 80°F

JOHN ISENHOUR

A Sterile Transfer Technique for Pure Culturing



Brewers using laboratory pure yeast cultures get cleaner fermentations, so you can figure the price of reduced contamination equals the cost of the lab culture. The propagation method described here minimizes contamination of the original culture and effectively decreases the cost of a single lab culture.

I will describe a technique I use to transfer sterile media. Liquid and agar culture media formulae and general procedures are discussed in *The Complete Joy of Home Brewing* (Papazian) and *Yeast Culturing for the Homebrewer* (Leistad), while pure culturing techniques can be found in *Brewing Lager Beers* (Noonan), and *Studies on Fermentation: The Diseases of Beer — Their Causes, and the Means of Preventing Them* (Pasteur).

The main concern when transferring sterile yeast from one container to another is eliminating contamination. I have found the best method is to imitate one developed for laboratory use, with improvisations. I started by building a sterile inoculation box, referred to in the lab as a "glove box." It provides an area in which a high degree of sanitation can be maintained for the culture to be transferred and to grow. The size of the box is not critical, as long as you have ample room to "navigate" within.

I made my first box of Plexiglas™, 32 inches wide by 16 inches deep by 16 inches tall. The top section (vertical sides and top) was made by allowing the sides to overlap and sealing the joints with silicon caulking. The top section rested on a flat Plexiglas™ base, with a neoprene gasket to provide a good seal against the bottom plate when the top was rested on the base. I cut two four-inch holes in the long side, to allow my hands to enter the box. I used duct tape to attach zipper-type plastic bags over the hand holes. By cutting the bottom out of one-gallon bags and taping the bottoms to the box, I could then "unzip" the opening to insert my gloved hand, and zip it closed to seal the box when I had finished. (See Figure 1.)

I next drilled a small hole in the left side and attached a piece of fish-tank tubing with silicon caulk. This was connected to a fish-tank air pump. In line with the fish-tank tubing, I installed a sterile filter from an IV piggyback set. (This and other items mentioned below were found in the bargain bin of surgical supply houses or mail ordered from surplus catalogs.) The air pump with the filter pumps positive pressure sterile air into the culturing environment. This keeps airborne contamination to a minimum.

Still having problems with airborne contaminants? Try this handy gadget. It's a new way to play doctor.

Once you have built the box you will need the following equipment to perform the sterile transfer: (See Figure 2.)

- Quart-size canning jars with rings and lids.

- Culture tubes (Pyrex 18 by 150 mm are my favorites) with septa stoppers from lab supply or surplus.

- Disposable or glass syringes (18 gauge or larger diameter needles are best). Check local laws, but I've had no problem purchasing them after explaining their use.

- Septa inserts for canning lids (surplus blood vial septa). Drill the appropriate size hole in each canning lid (buy extras because they tend to burr badly) and insert septa.

- Micro fermentation lock (I used needle and tubing left over from the IV piggyback, inserted the needle through the septa, and looped the connecting tube up into a blood vial half full of water to make a small fermentation lock). (See Figure 3.).

- Moist heat sterilizer (I use a Ritter SpeedClave for slants, gloves, syringes, etc., and an All American pressure cooker for canning jars).

Figure 1. Plexiglass glove box with zip-closure bags sealing openings.

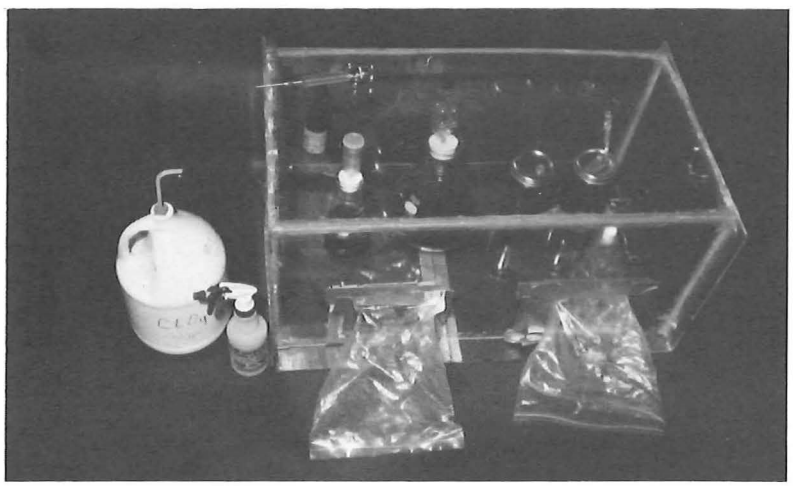


Figure 2. Equipment for performing sterile transfer and culturing.

Figure 3. Pierced canning jar lid forms micro fermentation lock.

Figure 4. Inoculating pure culture yeast into canning jar.

Before each use, sterilize the box by spraying with a plant mister filled with slightly over 200 ppm volume chlorine solution. (You can measure this with chlorine test strips, available at a restaurant supply house.)

Load your started lab yeast culture into the box, along with your sterilized canning jars with media, any tube slants for storage, and syringes for sterile transfer. I put my lab culture in a zip-closure bag which has been misted inside with chlorine solution.

Put on latex gloves, either purchased sterile or misted with chlorine solution, insert gloved hands in box and give the interior a final misting with the sterilization solution. Remove the lab culture from the outer zip-closure bag.

Remove the syringe from the sterile wrapping or take the glass syringe from the autoclave pan. Pierce the lab culture and withdraw a full syringe of liquid culture. Quickly transfer and inject the solution through the septum in the canning jar lid. (See Figure 4. Note: picture was taken outside of box, for visibility.) If you wish to repeat the procedure, or make slants for storage, flame the septum surface with a butane lighter as you insert the needle, draw up and remove the samples. Do the same when inoculating.

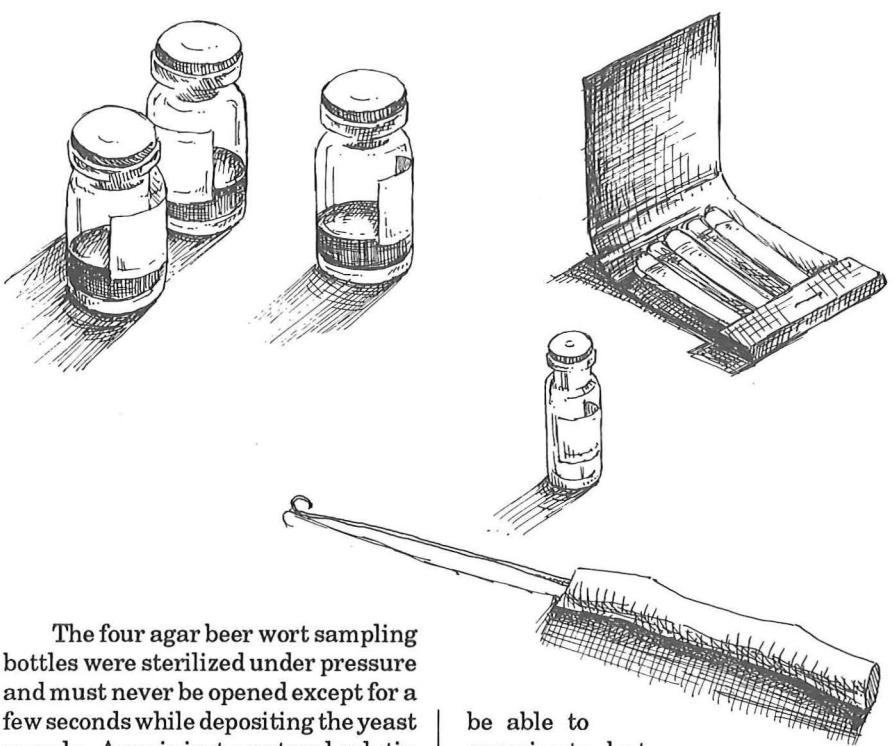
For canning-jar-sized cultures, insert micro fermentation lock needle through jar lid septum. For slants, follow cork-loosening procedures suggested in above references, or attach micro-lock.

Don't overdo it when flaming the septa. Some yeast cells in the needle may be damaged, but the majority will be OK. If the temperature in your working area is too cool [typically below 65 or 75 degrees F (18 or 24 degrees C), check the specifications on the lab culture], a pressure-cooked jar of distilled water with a little bit of Clorox can be added to the box with a Clorox-wiped fish tank heater inserted into it. This can serve as a heater for the box.

PIERRE RAJOTTE

Collecting Yeast While Traveling

I have friends who like good beer as much as I do, and who also travel a lot. During their wanderings they visit breweries where visitors are welcomed. Occasionally they are offered yeast when they mention they are homebrewers. Carrying live yeast on a vacation is not the best idea, so I have devised the following kit for gathering yeast on a brewery visit. People with no previous knowledge of brewing have successfully brought back yeast using the simple technique and equipment I have put together.



Yeast Sample Collecting Kit

The kit comes complete with:
The shipping box
3 or 4 sterilized agar beer wort sampling bottles with lids taped closed
1 sterilized water bottle with lid taped closed
1 inoculating wire with looped end
Matches to sterilize the stainless-steel inoculating wire

On the road again . . . but how do you take advantage of those far-flung yeast resources? It's easier than you think!

The four agar beer wort sampling bottles were sterilized under pressure and must never be opened except for a few seconds while depositing the yeast sample. Agar is just a natural gelatin that solidifies at room temperature; what is inside the bottle is just like a gelatin of unfermented beer.

The sterilized water bottle should be opened only when cooling the wire loop after sterilizing with flame.

For a person who has never done it before the following procedure may seem like overcautiousness, but consider the following: What you are about to perform is just like putting a seed in the ground to make a plant grow. In order for your plant to grow properly you must keep the ground around it free from weeds. When it gets big and well-established it will be able to defend itself and weeds might be able to germinate but won't make much headway against the big plant. In our case yeast is the seed, the solidified gelatin is the ground and the weeds are all around us in the air in the form of impurities such as microbes, bacteria and molds.

Imagine that all these impurities are like a light drizzle of rain and that you are trying to carry across the street some important papers that you cannot get wet. To achieve this you will cross the street quickly and cover your papers with your clothes. Once across, your papers will be safe and dry. This is exactly what you will be doing except that you will be carrying

yeast from one jar to another while keeping it free from contaminants. Because we are handling a very small quantity of yeast it is very important to keep it as free from impurities as possible. This way it will be able to grow slowly and multiply without any weeds (microbes, bacteria and molds) until it is large enough to ferment a batch of beer.

Procedure for Collecting the Sample

This should be done in the laboratory of the brewery where you will be collecting the sample, but is not absolutely necessary. Just get a small wide-mouth jar of fresh brewery yeast (your jar must be sterilized before filling) and find a table in a clean room. Do not sweep or dust before doing this or you will get too many contaminants floating in the air.

Your jar should have been sterilized in a pressure cooker, but if you don't have one the following procedure is good enough for our purpose.

First wash your jar with soap or detergent and rinse it many times with hot water so that no soap film remains inside. Then sterilize it with a solution of household bleach (sodium hypochlorite 5 percent) made by adding one tablespoon per gallon of water. Fill the jar with solution right up to the top, put the cover on, shake and let rest for one hour. Empty the jar and rinse it and the cover thoroughly with water that has been boiled and cooled in a very clean bottle or jar. Then fill your yeast collecting jar with boiling water up to the top and let it cool down while closed.

This is how you are going to bring it to the brewery. Empty the jar only when ready to put the fresh yeast inside and then the cover should be put right back on. Never leave it open for more than a few seconds. Think about the drizzle of bacteria and molds.

Now you have your sample with which to inoculate the agar-filled sampling bottles. Pick a drop of yeast with the inoculating loop from the big jar and put it on the surface of the solidified beer wort inside the bottle. The yeast drop will feed on the agar malt mixture and will grow and stay alive for a few weeks at room temperature or for a few months refrigerated.

When we receive the sample we take a drop of yeast, put it in a small bottle of liquid wort and let it ferment. We do this a few times in progressively larger bottles, being very careful of infection, until we get it large enough to ferment a batch of beer. As you can see, the clean primary collection of the yeast in a germ-free environment is of the utmost importance.

Because the yeast sample is very small, speed and accuracy in doing the transfer from the jar to your sampling bottles are extremely important. Now here's how we are going to do it:

(1) First loosen the cap of your yeast jar. It would be a good idea to get someone to help you perform this, especially the first time. He or she could open and close the yeast jar.

(2) Remove the tape from your sampling and sterilized water bottles and loosen the caps. Do not remove them.

(3) Light the match and put the flame under the loop end of the inoculating wire until it is red hot. This operation ensures that there are no germs adhering to the wire.

(4) Open your sterilized water bottle and dip the end of the loop in the water to cool.

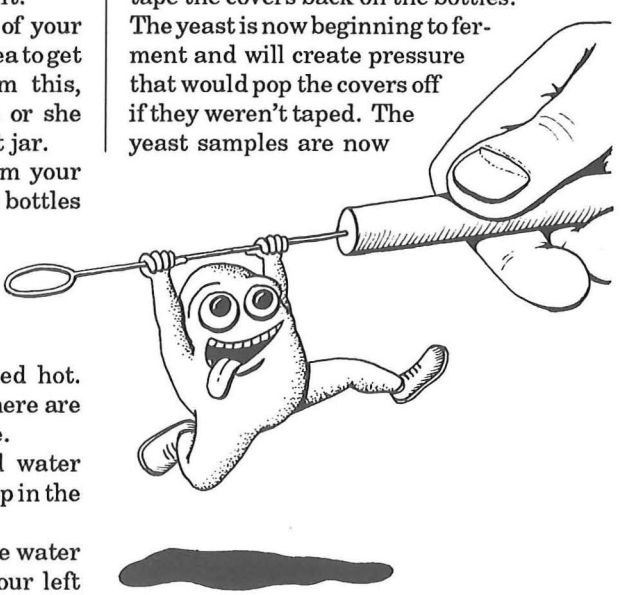
(5) Holding the wire in the water with your right hand, with your left thumb and forefinger open the first sampling bottle, keeping it as much in the horizontal position as possible.

(6) As soon as it's open the person in charge of the yeast jar should open the cover slightly so you can plunge the wire inside the jar and get a drop on the end of the loop.

(7) Quickly bring the wire holding the yeast drop to your sampling bottle and smear the surface of the agar with the loop. Remove the wire and put it back in the water and close the cover of your sampling bottle. Meanwhile your helper has covered the main yeast jar. The first time you do this you will wish you had four hands, but by the time you do the last bottle you will have become a real pro.

Remember as long as you act quickly and keep your wire in the sterile water between sampling you do not need to sterilize it with flame a second time. In case of doubt or mishandling it is better to flame it again.

The only thing left to do now is to tape the covers back on the bottles. The yeast is now beginning to ferment and will create pressure that would pop the covers off if they weren't taped. The yeast samples are now



ready for transporting or mailing. They do not need to be refrigerated as long as they are going to arrive at their destination within a few days. Do not forget to include with the sample a business card from the brewery on which you can write the remark, "Yeast sample. Do not open." This way customs officers will know that it is an official yeast sample and not some new drug and they will not be tempted to open the sampling bottle. Save everything to use next time. Shipping box, sampling bottles, sterilized water bottle (empty) and the inoculating loop.

The Yeast

Now a word about the yeast you will be collecting. Most breweries will give beer yeast to anybody who asks for it. Some people use it as a vitamin supplement (it is the best source of vitamin B) or as a skin cream (it does promote beautiful, healthy skin) and others use it to ferment beer. Although always perfectly good to use as a vitamin or skin cream, the yeast they give is not always suitable for fermenting a new batch of beer. It is sometimes yeast that has been discarded either as skimmings or as substandard for fermentation. It might be slow-acting or give a yeasty taste to the brew.

So make sure that you ask the brewer for their seed yeast, which is yeast from the batch they will use to ferment the next brew. That way the yeast will be good and healthy and raring to get going again in a fresh batch of wort.

Note: Sampling bottles are actually five milliliter serum bottles, available used from hospitals or medical labs. The water bottle is a two millilter bottle. If you have trouble locating them, you may reach the author at 5639 Hutchinson St., Montreal, Quebec, Canada, H2V 4B5, or by phoning (514) 277-5456. He will send you bottles for the cost of the postage.

PIERRE RAJOTTE

Collecting and Reusing Live Brewer's Yeast

I was first introduced to homebrewing 10 years ago at a conference at the Montreal Botanical Garden. The speaker mentioned that you had to make a starter with your packet yeast to get it going. He added that you could also keep yeast in the refrigerator in a clean bottle closed with a cotton wool plug, after primary fermentation was finished.

Within the next few weeks I was brewing and the first year I did three batches with the same yeast. They all tasted good to me. I was using malt extract and following the recipe that called for a can of extract and two pounds of sugar. I was to find out later that this particular extract was already 40 percent sugar syrup. After four years of this routine and different brands of extracts I felt that my beers needed an improvement to make them more beery tasting.

One of my relatives was a retiree from a major Canadian brewery and I asked him if he could get me some real brewer's yeast. "No problem," was his answer. Within a few days I had a private visit to the brewery with the brewmaster and I came home with two canning jars filled with lager and ale yeast. When I asked the brewmaster how to keep the yeast he answered, "Very simple! After primary, collect it in a clean sanitized jar, keep it in the fridge and reuse it within the next few weeks. They should be good for six to seven brews." I followed his advice and wow, what a difference! This was the kind of beer I wanted.

The last beer you made was great, and you know the yeast was a big part of your success. If only you could use it again! Here's how . . .

Since then I have refined my techniques and use various yeasts that come either from breweries, labs or are bottle cultured. I reuse them up to seven or eight times. I have never encountered major problems of infections or bad yeast.

In order to reuse yeast successfully I have devised the following procedure. The most important requirement is absolute cleanliness. You must ask yourself the question: "Can I wash and sanitize my brewing equipment better than anybody else?" The answer must be "yes," or you are inviting failure. To best achieve this, I recommend as must reading an article that appeared in the Summer 1983 (Vol. 6, No. 2) ***zymurgy***. The article is aptly titled "Yeast, Beasts and Disinfection," by George H. Millet. The information conveyed is essential knowledge for successful yeast handling.

Apart from cleaning and sanitizing solutions, very little equipment is needed. For collecting the yeast, I use glass jars or jugs of approximately one quart capacity. Jars with sharp shoulders are best because they permit easy decanting of the beer submerging the yeast. The jar must be closed by an airlock and you should check beforehand that the jar and the airlock on it fit in the refrigerator. Never use beer bottles that you close with a crown cap or any jar without an airlock. Collected yeast sometimes develops quite an activity and pressure, even in the cold. The bottles could explode if closed tightly or forgotten. The container can have either a small-mouth or a large-mouth opening. If you use a large-mouth container you will have to drill a hole for the airlock through the closure.

The first step is to physically clean your jar. I use household automatic dishwasher detergent. When I have inspected the container and am absolutely sure that there is no deposit of anything inside, I fill it with a solution of household bleach; one teaspoon bleach per quart of water. Let it soak for 10 minutes, empty and rinse with hot tap water. Then fill the container right to the brim with boiling water, really boiling water, put the cover on and let it cool down. I usually have quite a few of these already prepared.

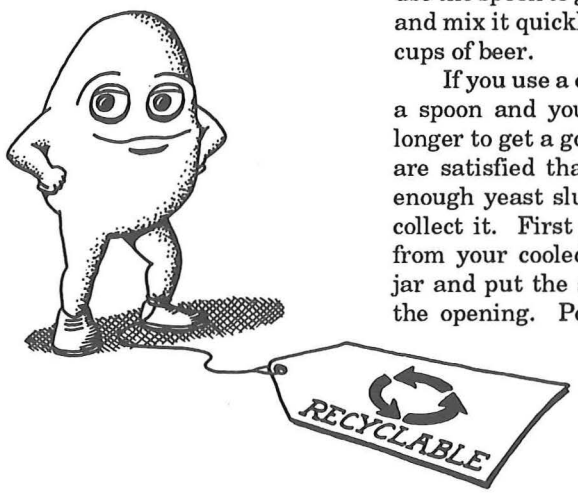
I always collect my yeast after primary fermentation is over. This procedure can be used whether you are fermenting in a plastic pail with a cover or in a carboy. When getting

ready to transfer to secondary, you will need your collecting jar, a closure for the jar with an airlock on it, a funnel and a long-handled spoon, preferably of stainless steel.

To sanitize the spoon and the funnel I submerge them in boiling water and leave them in for five minutes. At the same moment, I deposit the closure mounted with the airlock in a small container filled with about one-half or one inch of boiling water—just enough to cover the closure and the bottom of the airlock. Do not submerge the whole airlock in boiling water.

Meanwhile I am transferring to the secondary. When I get to the bottom, I remove the siphon and swirl the remaining cups of beer and mix them well with the yeast. Depending on the yeast strain, you will encounter some that are very powdery and mix readily and others that are as tight and compact as peanut butter. This is when you use the spoon to gather it up to the side and mix it quickly with the remaining cups of beer.

If you use a carboy you cannot use a spoon and you must swirl it a bit longer to get a good slurry. When you are satisfied that you have gathered enough yeast slurry you are ready to collect it. First you dump the water from your cooled sanitized collecting jar and put the sanitized funnel over the opening. Pour about an inch of slurry in it, remove the funnel and close the container with the airlock. The whole procedure takes about 10 to 15 seconds. Refrigerate your yeast immediately. Yeast kept this way can be successfully reused during the next two weeks. I have used yeast kept up to a month, but in this case you should feed it before pitching.



To feed the yeast, decant the beer that is submerging the yeast, making sure the closure and airlock are not deposited on anything. The beer by this time will have acquired a very harsh and yeasty taste and smell. This is caused by autolysis—the yeast feeding on itself. You need to have ready at this time a small quantity of sterilized wort. I always keep sterilized 10-ounce jars of wort ready for this. Before opening, shake the jar really well to mix in air. Then pour the contents into the yeast jar. The yeast will usually start fermenting within half an hour. As soon as the white froth develops it is ready for pitching. This should be done just as you are getting ready to cool your wort. Do not do it too long beforehand. Some yeasts are so active that they want to climb out of the jar through the airlock.

I have been using this yeast gathering technique successfully for the past six years. I have reused yeast up to eight times. Last year I had an opportunity to take a course in microbiology and quality control for the brewery. One of the first things I did was to check my yeast. I was extremely surprised at the quality. It had a degree of cleanliness and vitality that would have been acceptable for a commercial operation.

A benefit of reusing your yeast is that the more you use it, the better it gets, up to a point. Every time I have used yeast purchased from a lab I have never been overly enthusiastic about the first brew. But the subsequent ones have always been great.

Anybody can successfully reuse their yeast by following this simple and inexpensive procedure. There are only two requirements for success. First, the yeast must be clean and vigorous to start. Do not bother reusing the packet yeast from beer kits. Second, and most important, if there were a contest for cleaning and sanitation, you would win first place. There is no room in this field for sloppy brewers.

RODNEY MORRIS

Isolation and Culture of Yeast from Bottle-Conditioned Beers

You want to brew a beer just like your favorite microbrewery's. The ingredients are all there, but something's lacking. The yeast, of course! Here's how to get it.

Many varieties of commercially produced beer have viable yeast present that may be cultured and used to produce excellent homebrewed beers. I have developed techniques that any homebrewer may use to isolate and culture yeasts from a bottle of a favorite commercial beer containing viable yeast.

I use an enrichment culture system to increase my chances of isolating yeast from bottled beer that may have only a few viable yeast cells present. Select the particular bottle from which you wish to culture yeast and refrigerate it at least one day. If the yeast sediment has been disturbed in handling, leave the bottle in the refrigerator for at least one week so the yeast can settle.

You will need these materials:

- Dry Light Malt Extract
- Isopropyl Alcohol (Not rubbing alcohol)
- 16 x 50 mm screw-capped culture tubes
- Petri dishes, 15 x 100 mm size (Pyrex type are preferred, not plastic)
- Agar (technical or bacteriological grade)
- Phosphoric acid (optional)
- pH paper

Prepare some sterile malt extract in water. The resulting gravity should be about 1.040. Do not use a high-gravity medium, because poor recovery of live yeast may result. Pour this enrichment culture medium into some large screw-capped culture tubes or small bottles. If the pH of the culture medium is no higher than 5.0 the acidity will discourage bacteria and steaming the culture tubes containing the malt extract for 20 minutes will result in a sterile culture medium. Alternatively, you can sterilize the malt extract medium in the culture tubes with a pressure cooker for 10 minutes at 15 psi.

The bottled beer may have bacteria and wild yeasts present under the edges of the crown cap. It is necessary to sterilize the mouth of the bottle carefully to prevent bacteria from contaminating the yeast when culturing it. I have found that the most reliable method for sterilizing the bottle mouth is to wipe the cap with a cotton ball saturated with 95 percent isopropyl alcohol before opening the bottle. After uncapping, the bottle mouth should be wiped with the alcohol-soaked cotton ball, which is then discarded. Immediately ignite the film of alcohol on the bottle mouth. When the alcohol has burned off, pour all but about one-half ounce of beer

Sources for yeast culturing equipment.

This company sells supplies to homebrewers for yeast culturing:

Custom Chem Lab
2127 Research, No.10
Livermore, CA 94550
(415) 449-4371

This company has a large catalog of laboratory equipment and supplies, including items suitable for yeast culturing:

Carolina Biological Supply Company
Burlington, NC 27215

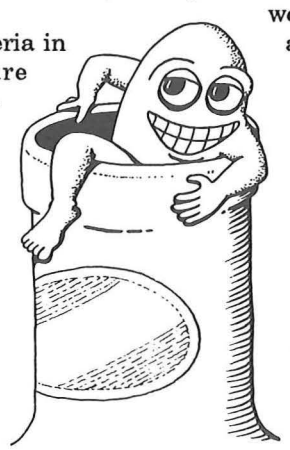
into a glass. Swirl the bottle to resuspend the yeast and pour the liquid into a large culture tube that is one-half full of the sterile malt-extract medium. Enjoy the remaining beer!

Leave the culture at room temperature (with the cap slightly loosened to allow CO_2 to escape) and examine daily for gas production (small bubbles rising to form a thin foam layer). If many cells of active yeast were present in the bottle, you should note gas production within one day. If only a few cells of barely viable yeast were present, you may wait several days for the culture to show evidence of yeast growth. I have never isolated live yeast if no growth is evident by five days of incubation. When you see growth, the yeast culture may be used to make a starter or be "streaked out" and a yeast colony selected to obtain a pure culture.

If you are certain that contaminating bacteria are not present, the culture may be poured into one to two quarts of sterile wort in a gallon bottle. Shake the bottle for a minute to aerate the wort. The oxygen that dissolves in the wort will stimulate the yeast to grow vigorously. Leave the cap slightly loose. When the fermentation subsides, place the starter bottle in the refrigerator for one day. The yeast will settle out. Pour out all but about one cup of liquid and swirl the bottle to resuspend the yeast. This slurry may be used to start a batch of homebrew.

I have found that some microbrewery-produced beers have considerable bacterial contamination. You must do some additional work to free your yeast from bacteria, if present.

The growth of bacteria in the enrichment culture may be considerably reduced by lowering the pH to 3.7 with acid. Do not use organic acids such as lactic or acetic to lower the pH, because they are only partly dissociated at this low pH and may inhibit the growth of the yeast. Use a strong mineral acid such as phosphoric acid to lower the pH. The yeast still will grow well at this pH. Growth of most, but not all, types of bacteria are suppressed at this pH so it is necessary to "streak out" some of the enrichment culture. Use an inoculating loop to remove a drop of the enrichment culture and transfer it to a malt-extract medium solidified with 2 percent agar (10 grams of agar added to 500 milliliters of malt extract medium, then sterilized and cooled) in a petri dish. Incubate the petri dish at room temperature for three days. Choose a well-isolated colony of yeast and pick up some of it with the inoculating loop. Transfer the clean yeast to a culture tube slant of malt-extract medium with 2 percent agar. Leave the slant at room temperature for one day for the yeast to grow, then store the slant in the refrigerator. The slant of yeast should be subcultured (some yeast is transferred to a new slant) at four- to six-month intervals. Your yeast



slants may be used later to prepare clean yeast starters for your homebrews.

I recommend starting with a bottle of Sierra Nevada Ale to practice your culturing techniques. I have always found this brand to have clean, bacteria-free yeast present with good viability. Another beer to try is Cooper Ale (not lager) from Australia. Some microbreweries use plate filtration followed by pressure bottling for their beer production. Although a slight amount of sediment may be present in the bottles, few, if any, viable yeast cells are found in such beers. Sediment in a bottle of microbrewery beer does not indicate viable yeast is present. I once found a loose, easily disturbed sediment in a bottle of microbrewery beer to consist of masses of bacteria and a few dead yeast cells.

Certain types of beers use bacteria in their fermentations to produce a desired flavor. I have found that the bacteria present in these types of beers do not grow well on solidified malt-extract slants. It is best to keep a mixture of yeast and bacteria from these types of beers in a liquid malt-extract culture in a small bottle or tube. Many of the Belgian beers have mixtures of bacteria and yeasts present in their bottles. Examples are Chimay and Oud Hoegaarden. If you wish to duplicate the flavor of these beers, you will need some of the bacteria in your fermentation.

Some Bavarian wheat beers (weizenbiers) have a live yeast present in the bottle (hefeweizen). Although a top-fermenting yeast is used to make the beer, a lager yeast is used in bottle conditioning.

The Berliner Weisse style of wheat beer uses a special lactobacillus in a secondary fermentation to give a dry, slightly acidic flavor. If you wish to duplicate this style, use a clean top-fermenting yeast for the first part of your fermentation, then add two quarts of a vigorous yeast-bacteria starter made from a bottle of this type of beer.

There is a large variety of bottle-conditioned beers from which homebrewers may make yeast cultures. California alone has 65 breweries and brewpubs, the majority of which have yeast present in their beers.

DARRYL RICHMAN

Running a Yeast Test

Now that other articles in this issue have whetted your appetite to try out new yeast strains, you'll need to know how to evaluate them. The same yeast makes the same beer, with perhaps the variety of color and bitterness created by other ingredients. So how do you decide which yeast to use for different beer styles? Experience makes all the difference.

Testing Goals

You can get some information about yeast strains by asking. For example, Wyeast provides a description of each strain it sells. But this is a very cursory description that advises you what to expect for a fermentation level and that the yeast has a particular flocculation level. How do you gauge this against what your current yeast delivers?

The only way to get the necessary experience is to try them out. And the way to try them out is with a yeast test. Before you rush into this, you need to think about what, exactly, you are trying to determine with this test.

The first goal of a yeast test is to know what you are testing for. You should write this down so you can refer to it later. Because everybody likes to get the most information for the least effort, you are likely to want to look for as many different characteristics as you can, some of which will be mutually exclusive. By writing down your goals, you won't stray from your intended purpose.

One goal you might have is to define the adjectives a manufacturer uses (high or low flocculation, for example) so you can know what to expect from them when you read their advertising. By comparing their yeast strain with one of your own, these terms will be defined by performance, and you will be able to read their descriptions of strains and know how they will act in your home brewery.

Another goal is to investigate what they *don't* say about the yeast—what kinds of aromas and flavors they bring to the beer. How will you know which of several ale yeast strains is appropriate for your India Pale Ale or your Flanders Brown if you don't smell and taste them beforehand?

By using the yeasts, you can also get a feel for how they act under your brewing and brewery conditions. For example, some lager strains need a diacetyl rest (a warming at the end of primary fermentation) while others work well without it. The need for this rest depends a great deal on the primary fermentation temperature. Other characteristics can be determined if you are careful to look for them: how quickly does the yeast begin to autolyze, how vigorous a fermentation does it produce and so on. These physical and metabolic characteristics can be as important to the finished product as any ingredient.

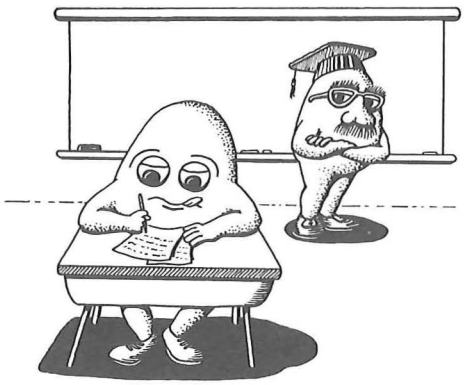
Yeast is a big part of a beer's flavor. Why not take yours for a test run and chart its course? It's fun, and the results may surprise you.

Designing the Experiment

Just like brewing itself, you should decide what you are going to do before you do it. If you just jump in, you may end up with little real knowledge. You must refer to your goals and decide how you are going to achieve each one. As you go through this process, you may discover that the goals actually conflict. If there is no easy way to remedy this, you may have to run separate tests.

The reason goals may conflict is that each different test investigates one changeable aspect of the process. This is called the *free variable*. Although it is possible to perform cross correlations to determine several trends when there are several variables, people get college degrees for understanding this. I'm not an actuary, and I'll assume that you aren't either. So for us, it's strictly one variable at a time. If your goals look like they force you to have several variables, you should run separate tests.

Fortunately, most of the tests you might want to run involve only one variable—the yeast strain itself. Therefore, you should only change the yeast you pitch; everything else should be identical. The yeast variable controls attenuation, flocculation, and ester and diacetyl production. The vigor of the fermentation can be noted, because a strong



primary has the ability to blow off unwanted sulfur compounds.

Of course, there are tests that might involve other variables. For example, temperature has a strong effect on the results produced by a given strain. But you'll have to run a separate test for each strain, because each one will react differently to a different temperature regimen.

As you decide what variables you are going to test, you will need to incorporate a standard into your test. If your goal is to understand what *high* and *low* flocculation mean when the manufacturer uses the terms, you will need to compare your results with those you get from a yeast that you normally use and have predictable results using. This is a *control*. Comparing the results you get from the control with your test strains is what leads to your understanding of the new strains.

Running the Test

The actual mechanics of running a test are to brew as you normally would. To eliminate unwanted variables, treat everything the same during the course of brewing. Since the variable is the yeast strain, this is easy. To test four new strains, brew five gallons of beer and rack the bitter wort into one-gallon bottles for fermentation. Pitch the four strains and your control strain in equal amounts, of course, and ferment them all under the same conditions. Be certain to handle each bottle just as if it were five gallons of your best.

In brewing beer for testing, it is best to pick a simple recipe. You want to highlight what the yeast is doing, not (necessarily) your virtuosity with ingredients. Keep it simple and brew a light bitter or lager, depending on the yeast under examination. A bigger or darker beer will just obscure the yeast's work. Also, a simple recipe is easier to duplicate for the next test.

Of greatest importance is taking careful notes. Be sure to observe the changes and write them down: How long was the lag phase? How long did it take to reach high kraeusen? How long did it take to clear? What kind of a head formed? Because this is an experiment, not *just* beer, you should take readings at least daily to monitor the attenuation. Without sophisticated equipment, getting objective numbers on the clarity (flocculation) of the beer is more difficult, but if you put a sample into a standard (for you) sighting glass, you can make comments about the clarity. A good sight glass is a test tube if you have one, or even your hydrometer tube.

Caution must be taken because, like Heisenberg's uncertainty principle, your measurements may affect the experiment. You will be intruding on the wort more often than you normally would and the volume is much less than you normally work with. These facts make it more likely that you'll contaminate one of the jugs and perhaps attribute the contamination to the yeast and not to your mistake.

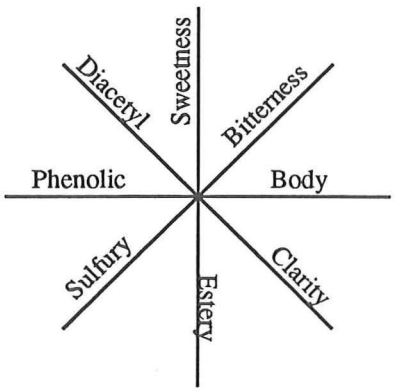
The most tedious job comes at bottling time. You know the routine: sterilize the bottling hose and bottles, get the siphon going, bottle, cap, clean up... *times five!* Be especially careful to measure out the same priming for each batch—higher carbonation levels increase the perception of certain beer characteristics. Try to get the same fill level on each bottle.

Examining the Results

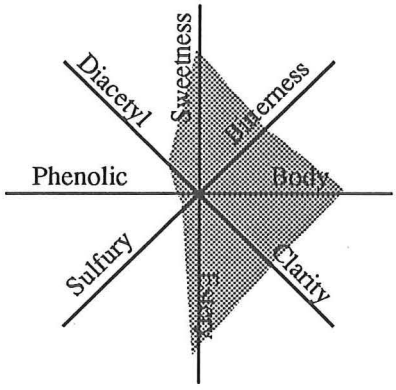
Before you begin tasting, be sure to let the finished bottles sit for two weeks. The beer is going through some final flavor changes and you want all the samples to come to rest before you take the results seriously. This is not to say that you can't taste them each day to determine what the changes are; but if your goal is to know what kind of finished beer the yeasts make, wait until they are done with it.

There are many ways to evaluate beer. Using a competition judging sheet is a good start, but it is really intended for another purpose. We are not trying to decide how good a bitter this beer is, but rather to pick up the intensity of different characteristics ostensibly affected only by the yeast strain.

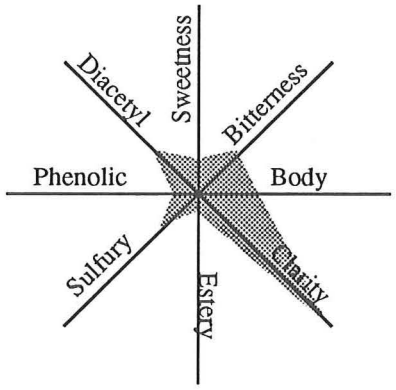
Perhaps the easiest way for a homebrewer to do this is by creating profile charts. These are charts that have a wheel with spokes radiating outward; each spoke is labeled with one of the characteristics to be examined. It represents the level of perception of that characteristic: None is at the center and "a whole lot" is at the outside. Using your control, mark a point on each spoke that represents the level for each characteristic. Then taste the sample strains and mark them on separate sheets. You can draw lines between the marked points to create a strain profile. A quick glance will tell you how the strains differ.



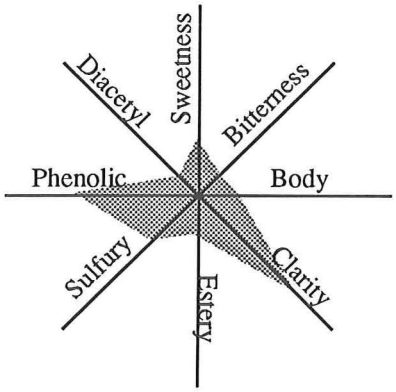
The figures show profiles for three different yeasts. But the lager



British Ale



Northern German Lager



Weizen

yeast was run at a separate test from the other two; it was lagered for three weeks, so it is hardly surprising that is was clearer than the others. Of course, using a lager is so much different from using an ale—if they were run under the same conditions, the information for one of the two types would not be of any practical use.

This is where we get back to designing the experiment: If you didn't ask the right questions at the beginning, you won't have the right answers at the end. If you draw your chart before you start, you'll know what you are looking for and will be able to get useful answers to your questions.

Besides the profile charts, you have your notes. Maybe you have to culture up a bigger starter for that one yeast that had a particularly long lag phase. The final gravity readings in your notes now tell you what *high* and *low* attenuation mean, as well as the yeast's ability to flocculate. But you have this information in your charts as well, if you asked about sweetness and clarity.

As you collect information, your ability to choose the right yeast for the style of beer you are making becomes quite refined. You will be able to create beers of subtlety and depth, and you'll be able to recreate them later, or tweak them to get the profile you want to achieve. It's another step forward from making scatter-shot homebrew to mastering the craft of brewing.

MARY MIRANDA, STEPHEN ASK,
JEAN-XAVIER GUINARD AND MICHAEL LEWIS, PH.D.

Analysis and Evaluation of Commercial Brewer's Yeast

All brewers acknowledge the contribution of the yeast strain to the final character of lagers and ales. Brewers also know all too well how difficult it is to produce and maintain vigorous, uncontaminated pitching yeast. Therefore it is perhaps curious that brewers do not enjoy a readily available commercial source of quality yeast in either fresh or dry form. Unlike other yeast users, such as distillers, winemakers and bakers, brewers recover their yeast for reuse. Over the centuries brewers have adopted many different traditional practices to select the yeast to be reused. Today one of the functions of microbiological quality control is to assure the quality of pitching yeast.

Homebrewers have always relied on dried yeasts, and the emerging microbrewing industry finds them of great utility. The yeast-producing industry now is asking whether it can supply the general brewing industry with yeasts as it does other yeast users. For those reasons, we accepted ***zymurgy***'s invitation to examine the dried yeasts currently available in the market.

Three general attributes of yeast always dominate discussions of yeast quality – microbiological properties, mechanical properties and sensory properties. Because brewer's pitching yeast is close to a pure culture, we usually think of these qualities as properties of the yeast itself, i.e., the specific *strain*. In this study, we have to think somewhat more broadly of the yeast culture, i.e., that mixture of microorganisms comprising the dried matter provided in the packet by the manufacturer. Nevertheless, the three attributes defined above provide a useful framework for assessment of yeast quality.

Homebrewers depend heavily on commercial yeast, but results can be mixed. Let's take a closer look inside those little packets and foil pouches.

zymurgy obtained the yeasts we examined directly from the producers (Table 1). In this way we avoided the criticism that the products have been maltreated in the trade (a real possibility, had we taken the yeasts from that source). However, we must make a few cautionary statements. The results reported here are but a snapshot of the products available — a picture of the yeast world made at a certain moment in time. Other batches of the same brand may be different from the one we tested; we make no claim that these yeasts are typical of the brand, or even randomly selected. Indeed, a wise manufacturer would have submitted a sample from a superior batch of yeast. We did not do these tests "blind," as we originally intended, because ***zymurgy*** understandably lacked the microbiological facilities to transfer the samples to coded containers. We did that. However, we did not consult the coding list until we completed all the tests.

How should a reader evaluate the data in these tables? The short answer is "cautiously." These data provide the numbers that could be used to castigate the dried yeast industry because their products fall well short of pure cultures. But for the most part these numbers do provide clear

Table 1.
Dry yeast samples tested

Ales

- A1 Paul Arauner KG
- A2 John Bull
- A3 CWE Home Brew Products
- A4 Doric Packet
- A5 Doric Bulk
- A6 Edme
- A7 Intek
- A8 Itona Products
- A9 Leigh - Williams & Sons
- A10 Munton & Fison
- A11 Premier Malt Products
- A12 Red Star
- A13 Vierka – Dark Munich (strong)
- A14 Whitbread

Lagers

- L15 Paul Arauner KG
- L16 Red Star
- L17 Vierka German Style
- L18 Whitbread
- L19 Intek

Liquid Samples

- L20 M. eV. American Lager
- L21 M. eV. German Lager
- A22 Wyeast American Ale

perspectives about yeast quality, although they do not substitute for personal experience and preference. At the simplest level, the "best" yeast culture is one that is pure yeast, that is to say, it has no bacteria, is one kind of yeast, is the right kind of yeast, is 100 percent alive and produces no detectable off-flavors. In a specific commercial setting (e.g., any large brewing company) this definition is a valid one, and such quality is obtainable and necessary. Thus, for a specific product we can decide what are off-flavors and if culture purity promotes processing and flavor consistency and safe reuse of yeast.

But these are not the primary concerns of small-scale brewers where a yeast is (or can be) used once and discarded. Nor where we cannot define what an off-flavor is for an unknown product or how a particular flavor will be perceived by a consumer. A small brewer may choose to exchange beer predictability and consistency for the flavor complexity that a mixed culture can impart to a product. In short, the ideal of yeast culture purity espoused and exploited advantageously by big brewers does not necessarily translate to the small-scale scene. (However, we note that a mixed culture is a desirable mixed population; it is not the same as filthy yeast.) Not one of the dried yeasts we tested is a pure culture. The point we wish to make is that this does not necessarily damn them as brewing yeasts in the small-scale setting. In contrast, the yeast must be highly viable (if for no other reason than a customer should not pay for dead yeast) and vigorous. We found a wide range in viability and vigor among the samples. Finally, enteric bacteria and food poisoning organisms such as *salmonella* should always be absent for obvious reasons. We found three samples containing low levels of these bacteria.

Procedures

Because the commercial market for dried brewer's pitching yeast has been relatively small, we lack standards and methods for evaluating it. In this study we have borrowed some practices and quality criteria developed for evaluating baker's active dried yeast and others developed for the evaluation of fresh brewer's pitching yeast. We think these methods are good ones.

Preparation of yeast samples: We suspended one gram of each dry yeast in 100 ml of peptone water at 100 degrees F (37 degrees C). After 15 minutes, we counted the total number of cells present in the suspension using a hemocytometer. We repeated the count after staining with methylene blue to estimate the proportion of dead cells. We did this twice to get reproducible values that we then used to calculate appropriate dilutions of the original suspension to give 100 to 400 "colony forming units" (CFUs are cells or clumps of cells capable of growing) per test plate. The liquid samples were prepared in accordance with the written instructions provided with each culture. Yeast A22 was cultured in the foil pouch by breaking the inner seal. This took two tries because the seal was not broken with the first try and it took a day or so to realize no growth (gassing) was occurring. Yeast L20 and L21 were inoculated into the nutrient broth prepared according to instructions. Counts of the liquid yeast were made after the prescribed time when growth of L20 and L21 had subsided, i.e., five days.

Plating Media: Small amounts of the suspension, appropriately diluted, were plated on WL Nutrient Agar (from Wallerstein Laboratories) and YM Agar (from Difco). We evaluated the colonies that grew by their gross visible characteristics and under the microscope. We searched for *petite* (respiratory-deficient) mutants using an overlay method that employs triphenyltetrazolium red. Such non-respiratory mutants grow at a much reduced rate and may contribute to off-flavor. We searched for wild yeast using WL Differential Agar. This medium contains a green dye that wild yeasts do not absorb (brewer's yeasts take up the green dye preferentially). We also used *Lactobacilli* MRS medium containing 40 ppm of actidione to reveal wild yeasts. We used WL Differential Agar containing 40 ppm actidione (to suppress yeast growth) to look for contamination with bacteria, and the more specific *Lactobacilli* MRS medium (incubated anaerobically) for lactic acid bacteria. We used Brilliant Green Agar to find *Salmonella* species and MacConkey's Agar to detect enteric bacteria.

Yeast Vigor and Flavor Attributes: We estimated yeast activity by pitching three grams of rehydrated yeast into three liters of 12 degree

Plato wort made with pale malt syrup and with a low hopping rate. We measured yeast growth and decrease in Plato every six hours until the level of yeast cells in suspension leveled off and began to decline (about 52 to 56 hours). A gallon of wort was fermented at the same time and bottle conditioned for 10 days. We used this beer to evaluate each yeast's contribution to beer flavor, paying special attention to off-flavors. Our taste panel consisted of seven people all experienced in beer flavor evaluation and brewing on a small scale. The judges first evaluated the beers independently in tasting booths using our standard score sheet. After these results were tabulated, the panel met again to retaste the beers to confirm the first results and to agree on an overall numerical rating of quality for each yeast.

Results

We judged the yeasts in three general categories: microbiological quality, mechanical performance (Table 2, Figures 1 and 2) and sensory performance (Table 3).

Microbiological Quality (Table 2): In all but three cases we detected no *Salmonella* and/or enteric bacteria. Even though it is unlikely that these food poisoning and spoilage bacteria would cause beer spoilage, their absence indicates at least a reasonable level of sanitary operation in the producing plants.

Lactic acid bacteria are of most concern to brewers. Their presence in almost all cases is undesirable because of the flavor they contribute (usually sour). This depends not only on the total number of bacteria present, but also on the vigor of the yeast culture of which they are a part. A vigorous yeast tends to suppress growth of lactic acid bacteria. Of the 22 cultures tested we found eight to have serious bacterial contamination and nine of the samples to have moderate contamination; one dried yeast (A13) and the three liquid samples had a very low or non-detectable level of contamination.

The presence of lactic acid bacteria coupled with low yeast viability and vigor uniformly caused sour-acidic characters in the resulting beers. In

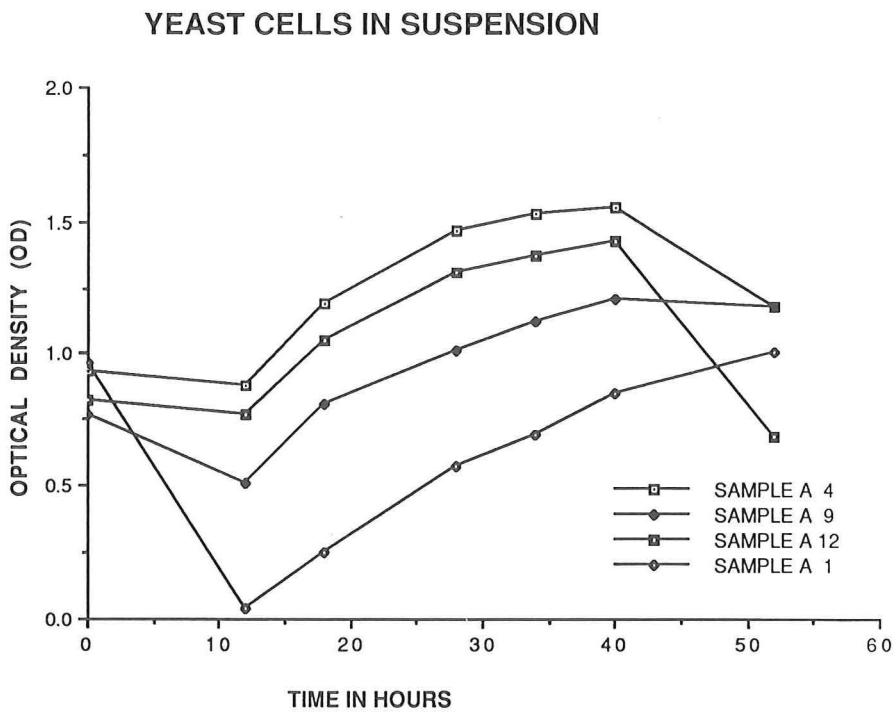


Figure 1. Growth of the pitching yeast is reflected as an increase in turbidity of the wort. Turbidity is measured optically in a spectrophotometer at a wavelength of 660 nm and plotted against time. Decreases in turbidity after 40 hours demonstrate the yeasts' tendency to flocculate at the end of fermentation.

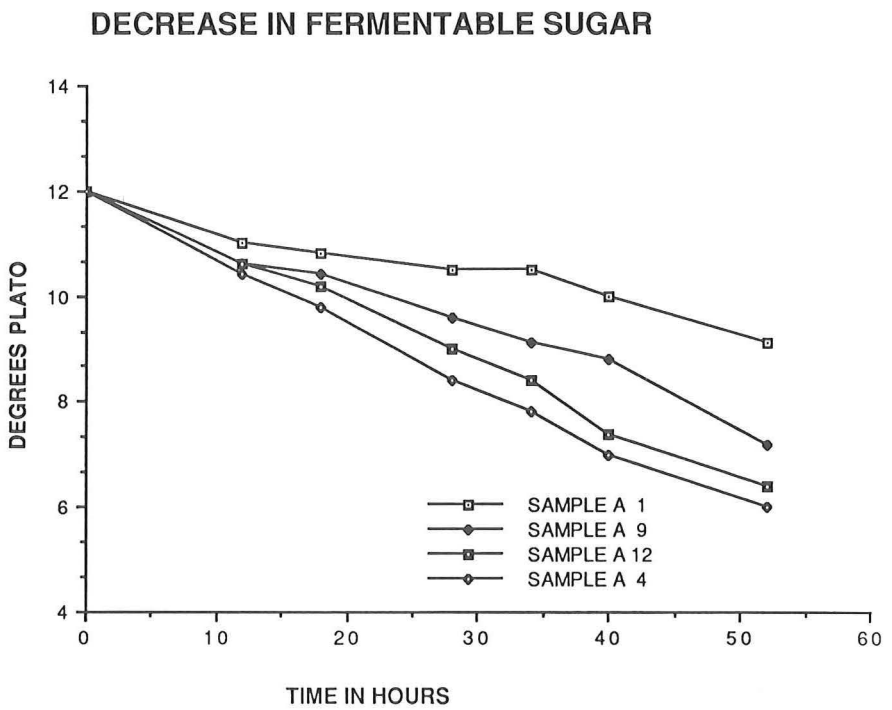


Figure 2. As the yeasts grow, their metabolism causes a decline in the amount of sugars in solution as measured in degrees Plato, using a refractometer. The absolute measure of the fermentable sugar becomes less accurate with time as alcohol is produced because alcohol changes the refractivity of the wort in a manner different from sugars.

Table 2. Yeast Microbiological Quality and Mechanical Performance

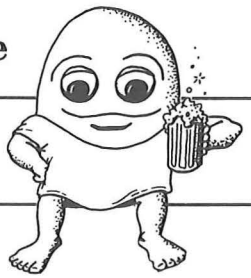
Strain	CFU/G*	% Viable	Fermentation Rate (°P/Day)	Doubling Time (Hours)	Lactic Count**	
A1	200	69.2	1.34	4.21	High	2,500
A2	2,100	55.6	1.43	12.28	Intermediate	952
A3	8,500	40.3	1.57	23.53	Low	35
A4	14,000	87.1	2.77	21.42	Low	57
A5	6,350	56.7	2.98	29.83	High	1,435
A6	14,000	47.7	1.52	32.58	Low	43
A7	3,300	66.7	1.44	2.46	Intermediate	697
A8	14,200	52.2	1.94	55.42	Intermediate***	414
A9	6,700	31.4	2.22	16.04	Intermediate	537
A10	14,500	48.0	1.57	33.25	Intermediate	414
A11	12,500	48.1	2.63	17.16	Low	50
A12	835	47.1	2.58	20.82	Intermediate	417
A13	6,700	52.9	1.29	28.24	Low	0
A14	4,300	36.4	1.48	5.17	Intermediate	140
L15	655	47.1	1.48	19.65	Very High	21,212
L16	6,400	57.9	2.16	10.58	Intermediate	141
L17	9,350	85.2	1.48	29.01	High	6,809
L18	7,300	66.7	1.98	11.03	High***	3,562
L19	365	17.4	1.66	47.61	Intermediate***	417
L20	17	74.3	1.19	8.66	Low	0
L21	73	84.1	1.21	7.34	Low	0
A22	7.5	90.2	1.26	5.78	Low	0

* indicates millions of colony-forming units (CFUs) per gram dry weight
** colony-forming lactic acid bacteria per 10 million viable yeast
*** indicates low levels of enteric bacteria and *salmonella* also detected

the case of yeast L18, there was a fairly high lactic count, but good yeast viability and vigor allowed the yeast to outgrow the infection and produce a beer with only a slight defect (Tables 2 and 3). Reuse of yeast puts great stress on yeast quality because contaminating bacteria can grow at an alarming rate during a fermentation. Yeast and yeast-handling practices that may be microbiologically acceptable for a single use (as in a winery or a bakery) may be quite inadequate for repeated use.

Most "wild" or non-culture yeasts produce beer with a phenolic-medicinal character and many beers made with the yeasts tested here displayed this sensory quality (common for beers brewed on a small scale). The behavior of these yeasts on WL Differential Agar was not entirely atypical of brewer's yeasts, but was idiosyncratic. The yeasts that caused phenolic-medicinal characters displayed resistance to copper sulfate at 160 ppm and even up to 200 ppm in some cases, which is not typical of normal ale yeasts. Generally these yeasts were not mixtures of yeasts; that is, phenolic-medicinal character did not appear to derive from contamination by a few wild yeast cells, but from the

Table 3. Sensory Performance



Strain	Sensory Characteristics	Overall Quality	Overall
A1	highly phenolic, sulfury, lactic sour, winy, cidery	poor	0
A2	fruity, acidic	good	7
A3	phenolic, rancid, cidery, worty	inferior	2
A4	phenolic, fruity, apple	average	4
A5	phenolic, cidery, fruity, slightly sour	average	6
A6	yeasty, rancid, worty	average	5
A7	phenolic, slightly fruity	average	4
A8	worty, cardboard, oak, vanilla	average	6
A9	highly phenolic, lactic sour	inferior	2
A10	floral, slightly fruity	good	8
A11	slightly phenolic, spicy, slightly sour	average	4
A12	very highly phenolic	poor	0
A13	strongest phenolic	poor	0
A14	vanilla, honey, floral	good	7
L15	highly phenolic, lactic sour	poor	0
L16	phenolic, slightly sour, fruity	poor	0
L17	highly phenolic, lactic, butyric, rancid	poor	0
L18	slightly lactic sour, cidery, clean	good	8
L19	very highly phenolic	poor	0
L20	slightly sulfury, yeasty, fruity	good	8
L21	slightly phenolic, fruity, yeasty	average	4
A22	sulfury, yeasty, banana, apple, floral	good	7

culture at large. This suggests that the culture yeast could have been substantially replaced by a contaminating yeast during production. Ale and lager yeast produced by the same company displayed the same defects and scored similarly in sensory attributes (See Table 3).

Only two (L18, L20) of the seven strains submitted as lager yeasts displayed the typical test behaviors that distinguish lager yeasts [such as fermentation of the sugar melibiose and inability to grow at 98.6 degrees F (37 degrees C)]. This indicates that a contaminating yeast displaced the culture yeast in production (see above), or that there was some carelessness among producers in matching the contents of a package with its label.

Mechanical Performance (Figure 1 and Table 2): When first suspended, some of the yeasts displayed a very strong tendency to remain in clumps, making it difficult to count total cells and the proportion of dead cells. Inability to resuspend fully is a potentially negative quality because such yeasts will tend to sink quickly to the bottom of a fermenter and initiate fermentation only after a long lag. Strain A7, for example, fermented slowly and remained on the bottom of the vessel throughout fermentation. Strains A9 and L18 remained clumped initially, but suspended adequately during the first 20 hours of fermentation. Clumping is not the same as flocculation of yeast at the end of fermentation, but more likely reflects yeast nutrition during production. Figure 1 illustrates the effect of yeast "clumps" and a range of fermentation qualities. Typical yeast has a doubling time of 16 hours. Sample A1 has an apparent doubling time of only four hours but this value is misleading because of its initial clumped state.

Sensory Properties (Table 3): We conducted sensory evaluations of

the beers produced by the yeasts under test. We accentuated the effect of the yeast by employing a pitching rate that was about three times the average rate and by using a relatively low-gravity, pale-malt wort that was weakly hopped. This resulted in a bland product in which the flavor contribution of the yeast could easily be detected and assessed. Some beer products are delicate in flavor; in these, the least error in processing, including yeast quality, shows up in compromised product attributes. For this reason, in our sensory evaluations, we strongly downgraded yeasts that produced off-flavors, the most common of which was phenolic-medicinal (wild yeast) flavor. Interestingly, we did not detect diacetyl in any beers, probably because all our beers were bottle conditioned. They therefore enjoyed a protracted yeast contact for diacetyl reduction. We do recognize that a flavor attribute that may be a disaster in a delicate lager may be desirable, or at least acceptable, when contributing to a maelstrom of flavor impacts in a "big" beer. What constitutes a desirable flavor remains a personal preference, although we have applied a professional standard.

Nine of the 22 yeasts earned a "poor" or "inferior" rating from our panel, i.e., scored two points or less on our 10-point "overall" scale. In every case these yeasts gave phenolic-medicinal (wild yeast) flavors often allied with sour, rancid and cidery qualities that we associate with bacterial action. These qualities also were present at a detectable but much lower and probably acceptable level in seven yeasts we characterized as "average" and scored three to six on our 10-point scale. The remaining six yeasts, including two of the three liquid yeasts, received "good" ratings, or numerical scores of seven points and above.

Conclusion

The most important characters of a dry culture yeast for brewing are: (1) fidelity to type of the strain or strains included, (2) the microbiological purity and viability/vigor of the yeast, and (3) the flavor of the beer produced. We conclude from our study that there is ample room for improvement of dried yeasts in all three categories of evaluation. For the small-scale brewer acquiring good yeast remains a most difficult task.

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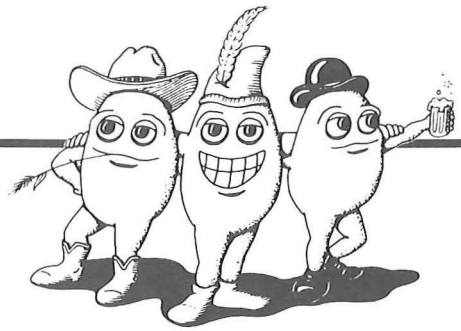
BYRON BURCH



Of Yeasts and Beer Styles

When choosing a yeast for a particular style of beer you actually face a more complex series of choices, conscious or unconscious, than you may realize. Not only that, your choice may well be a lot more important than you think. For some years now, I've been dividing my 10-gallon batches into two and pitching each half with a different yeast. When I first started these tests, I was astounded to see how different the resulting products were. Sometimes the two halves were totally different beers. These experiments gave me a new awareness of the yeast selection process and its importance. What factors, then, influence my choice when I'm selecting a yeast strain, and what effect does my decision have?

First, because of my experiments, I no longer use or recommend dried yeasts for most homebrewing purposes. It's not that they've gotten any worse lately, it's just that the alternatives have gotten considerably better. I believe the advent of real commercial brewing yeasts in laboratory-pure, liquid cultures is one of the biggest advances in homebrewing in the past several years. They are more expensive than dried yeasts, but I think they're worth every penny. It's no accident that most prize-winning beers in major competitions these days use liquid cultures.

If it weren't for these cultures, I'd have a difficult time trying to make any yeast recommendations at all, knowing this article will be in print for a number of years. I can't think of a single dried beer yeast that's been consistently free of contamination during the years I've been brewing.

This being so, the question becomes whether contamination is sufficient to cause real problems for beer. Based on my own experience as well as customer complaints, I'd have to say the answer all too often is affirmative. What is more, the problems with a given lot of yeast aren't always immediately obvious until it's too late. That's why I recommend dried yeasts only in two cases: first, with relatively stable, high-alcohol beers (barley wines, imperial stouts, etc.) where a wine yeast strain with a high alcohol tolerance is in order (a high-alcohol content helps keep the beer stable); and second, for real ale types of beer that are consumed within three weeks of brewing. It's always possible to have a contamination problem with a given lot of any yeast. However, experience tells me the chances are relatively remote when dealing with a reputable source of liquid cultures.

Once the decision of liquid or dried yeast has been made, we move on to the question of ale *vs.* lager yeasts. Most homebrewers distinguish between "top-fermenting" ale yeasts and "bottom-fermenting" lager yeasts. However, as Gary Bauer pointed out in the 1985 ***zymurgy*** All-grain Special Issue (Vol. 8, No. 4), such a classification is considerably oversimplified. Bauer delineates five basic types of ale yeasts:

(1) True top-fermenting ale yeasts that rise to the surface and are removed by skimming.

(2) Ale yeasts that settle to the bottom of the fermenter, much like lager yeasts. This class includes most dried yeasts for homebrewers.

(3) Altbier yeast: a special strain used to ferment German-style ales.

(4) Weizenbier yeast: a unique strain that produces the esters and phenolics common to Bavarian-style wheat beers.

(5) Strong beer yeasts: top-fermenting yeasts similar to wine yeasts in that they can ferment up to an alcohol content of 10 percent by volume.

In addition, Bauer points out that lager yeasts also are subdivided, depending on whether they attenuate weakly or strongly, and flocculate rapidly or stay a long time in suspension. I recall reading almost 15 years ago that there were 65 recognized substrains of lager yeast, so as you can see this subject gets complicated.

Ale yeasts are actually distinguished from lager yeasts not by the traditional "top and bottom fermenting" designations, but by the fact that lager yeasts ferment trisaccharides such as melibiose and other minor sugars, while ale yeasts don't. Even this water is muddied, however, by ale yeasts like Sierra Nevada's, which do ferment the trisaccharides.

Temperature ultimately provides the best way to distinguish between ale and lager strains. This is true both at the theoretical level (lager yeasts stop growing at lower temperatures than do ale yeasts) and at the practical level, which is my interest here.

Obviously, different beer styles require different yeasts, but choosing the right one can be tricky. Here's some help.

Practically speaking, the next decision you make in selecting a yeast strain should be based on temperature; specifically, the anticipated temperature of your fermentation. As a rule of thumb a lager yeast should never be used if your fermentation temperature is expected to be above 65 degrees F (18.33 degrees C), and an ale yeast should almost never be used if the temperature is expected to be below 55 degrees F (12.78 degrees C), though some ale strains may stay active as low as 50 degrees F (10 degrees C). Either ale or lager yeasts may be used between 55 and 65 degrees F (12.78 and 18.33 degrees C).

Having said that, I want to stress that a given yeast should be selected for a particular beer on the basis of one or more of its characteristics [e.g., ferments melibiose, or works well at 45 degrees F (7.22 degrees C), or is a good reducer of diacetyl]. What is most important is the way the yeast behaves. Nothing is less important than the question of whether a given yeast is technically a lager strain or an ale strain, as long as it gives you results suitable for the beer you're trying to brew. I know one first-rate brewer who routinely uses a lager yeast for pale ales and wins awards, too. I know another homebrewer (one of the best in the country) who admits to using a particular ale yeast once in a while for making lagers. These people are not dummies, though if you're going to break the "rules," you should always know why you're doing so.

Before going on to talk about specific yeasts, I want to mention yet another way in which yeast strains may be differentiated, giving us another step in the selection process. I find it useful to distinguish between those I perceive as relatively neutral and others that are complex and distinctive. Ever since the first single-cell yeast culture was isolated just over a century ago, there has been a trend toward the neutral yeasts and away from the individually distinctive beers of years gone by.

The development of refrigeration and the isolation of cold-tolerant lager yeast strains in the 19th century worked hand in glove to revolutionize brewing. For the first time it was possible to consistently brew beers with a "crisp, clean" flavor profile. Fermenting in the 40- to 50-degree F (4.44- to 10-degree C) range meant that the customary fruity esters caused by the traditional, warmer [60 to 70 degrees F (15.56 to 21.11 degrees C)] fermentations could be avoided. "Crisper, cleaner" fermentations requiring the most up-to-date technology came to be seen as "modern" (perhaps even "trendy"). With the coincidental revolutions in other areas such as glass manufacture, transportation and shipping capability, the innovation spread like wildfire, and soon came to dominate much of the brewing world. Today the presence of esters in beer continues to be associated with the traditional ale styles, while their absence distinguishes the lagers. Many homebrewers think of ester formation as a distinguishing characteristic of ale yeast strains, but this is true only in a limited sense. It would be accurate in most cases to credit the higher fermentation temperatures at which these strains must do their work. It's possible to make lager yeasts behave similarly.

All this history has left many of us with a bit of prejudice in favor of the more neutral-flavored strains of yeast, a prejudice reflected in such descriptive words as "clean." Recently, however, an encouraging sign has been the trend away from centralized technological brewing, as practiced by the U.S. megabreweries, and a rediscovery of individuality, as seen in the homebrew, microbrewery and brewpub movements.

Even here our tastes have been conditioned, and when we sample homebrews in our own kitchens or down a pint at the local brewpub, most people expect a product with some of those crisp, straightforward characteristics we've been taught to look for by all the light lagers we've consumed. Perhaps it's inevitable, but it seems a shame that some interesting and perfectly good yeast strains don't get the attention they might really deserve, while by far the two best-selling liquid yeast strains (at least for my company) are the ale and lager strains that rank as the "crispest, cleanest and most neutral" of their respective classes. When such terms are used here, by the way, they are only used descriptively, with no implied value judgments of any sort.

The following recommendations should be considered personal, rather than definitive. Note that strains can mutate rapidly and may change over time. Therefore characteristics of the same strain may vary somewhat when obtained from different suppliers who maintain separate cultures.

Lager Yeast Strains

St. Louis Lager Yeast (Wyeast No. 2007, M. eV. Research No. 4) is an archetypical yeast of the "crisp, clean" type. It does not accent body and produces pointed rather than rounded flavors. Most noteworthy is a slight essence of "roses." Notoriously unstable genetically, it does not adapt well to home culturing. Nonetheless, it is as good a yeast as I've used for American light lagers. Flocculation is medium. Use this yeast whenever a "clean" characteristic is desired and "full mouth feel" is not really an issue.

New Ulm Lager Yeast (Wyeast No. 2035) also is an American lager strain. Not as crisp as the St. Louis, it produces more complexity with the accent on fruitiness. Because of this, it's excellent in "California-style" wheat beers. Used in light lagers, this yeast produces beers that are either loved or not loved. I know a number of people who really dislike this strain, and a smaller number who would use nothing else for their lager beers. Flocculation is medium.

German Lager Yeast, W. No. 308 (Wyeast No. 2308) is a great, rich, complex yeast that accents maltiness. It has produced several prize-winning brews, but only when treated just right. The first two-thirds to three-quarters of the fermentation should take place at 45 to 48 degrees F (7.22 to 8.88 degrees C), and the end of the fermentation at 60 to 65 degrees F (15.56 to 18.33 degreees C). The beer should then be chilled down to the 30s (about -1.11 degrees C) for a day before separating from the lees. If not treated properly No. 308 can be somewhat unforgiving because of its tendency to produce high levels of diacetyl (undesirable in lagers). Flocculation is medium. Use for all full-bodied continental lager styles when a malt accent is desired.

Bavarian Lager Yeast (Wyeast No. 2206) is a relatively new strain, at least to me. Once again the accent is on maltiness and complexity. This yeast is very similar to No. 308, although the latter may bring out the hops just a bit more. However, No. 2206 has the advantage of being less fussy. Flocculation is medium. This yeast is good for bocks, but may be used whenever No. 308 might otherwise be the choice.

German Lager Yeast (M. eV. Research No. 37) is similar to the preceding strain, and may share the same origins.

Danish Lager Yeast (Wyeast No. 2042, M. eV. Research No. 55) is another complex continental strain with a unique character, but here the accent is a bit less on malt and perhaps a bit more on hops than with the German yeasts. Flocculation is low. Use for continental Pilseners, and especially Dortmund-style exports.

Swiss Lager Yeast (M. eV. Research No. 12) is a clean-flavored yeast that ferments vigorously at 50 degrees F (10 degrees C), but produces a significant amount of irreducible diacetyl at warmer temperatures. Use for Pilseners and especially for American lagers, but only if fermenting under refrigeration.

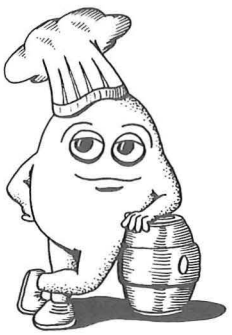
Ale Yeast Strains

Chico Ale Yeast (Wyeast No. 1056, M. eV. Research No. 72) is a classic example of the clean and neutral ale yeast strains coming more into favor. Actually, this strain behaves like a lager yeast in some ways,

continued on page 63

KURT DENKE

Fleischmann's (aka Budweiser) Yeast



Anheuser-Busch corporation used to make a product known as "Budweiser Baking Yeast" for the commercial baking industry. They still make it, but it has been sold to Fleischmann's and is now available under the name "Fleischmann's Yeast." This is not spent yeast from their fermenters; but is grown by Anheuser-Busch with a co-packaging arrangement with Fleischmann's. What's important is that it works great for homebrew! The yeast is sold in two-pound and five-pound bricks wrapped in paper. The price is quite low (about $1 for two pounds wholesale), although my local distributor will usually sell it only in case lots of 25 bricks. The yeast has been mixed with a bit of cornstarch in order to make the bricks solid, but this does not seem to be a problem in using the yeast.

I take a two-pound brick and slice away the outside, which has been in contact with the wrapper, with a sterilized knife. For a five-gallon batch, I'll use about three ounces, which amounts to about three cubic inches. Because the amount of yeast pitched is so generous, the fermentation usually gets under way within a few hours, in sharp contrast to my experience with liquid yeast cultures, which tend to start and ferment very slowly.

I have never used Budweiser Baking Yeast in a room-temperature fermentation, and so can't predict how it would behave, but I have used it several times in a modified refrigerator where the primary fermentation is at 50 to 52 degrees F (10 to 11 degrees C).

After the primary fermentation is over, I lower the temperature by about three degrees per day until I hit 38 to 40 degrees F. After several weeks of lagering, I give it a final week at 34 to 35 degrees just to help clarify it.

My results with this yeast have been wonderful. The flavor is extremely clean and lagerlike, and I have been able to brew beers of very light, delicate character that are comparable in their cleanliness of flavor to commercial beers. My brewing partner, Pam Moore, and I made a honey ginger lager with this yeast that won first place in the 1988 AHA National Competition herb beer category. I am told we came painfully close to winning Best of Show.

I believe this yeast is a tremendous asset to the homebrewer who wants to produce good lager beer at home. The liquid cultures that are available are very pure and uncontaminated, but seem rather weak when first pitched. With the Fleishmann's Yeast, a single two-pound brick is more than enough for a single batch, and it is possible to pitch three ounces of yeast (equivalent to the common commercial pitching rate of one pound per barrel) and get the fermentation off to a healthy start.

If you want to find Fleischmann's Yeast (which is **not** the same as "Fleischmann's Yeast Direct" on your grocer's shelf) you can call their Customer Service number for a distributor in your area. Dial (800) 722-3971 if you live in California, (800) 241-3608 from anywhere else. If you need some help or want to exchange notes, give me a call in Philadelphia at Home Sweet Homebrew, (215) 569-9469, or leave me a message on CompuServe.

JEAN-XAVIER GUINARD

Lambic: A Unique Combination of Yeasts and Bacteria

Lambic beers from Belgium are among the few beers still made by natural or spontaneous fermentation of wort. Lambic wort is made from 40 percent unmalted wheat and 60 percent malted barley. It is boiled for several hours with aged (*suranné*) hops which impart very little bitterness. The wort is cooled overnight in a shallow tray (*bac refroidissoir*), usually in the attic of the brewery, where the wort picks up the natural microbial flora from the atmosphere. The next morning the inoculated wort is run into large wooden casks where the fermentation takes place over a two-year period.

The combination of microorganisms involved in the lambic fermentation is unique. It is comprised of yeasts and bacteria, a truly surprising fact for most brewers who recognize the yeast strains *Saccharomyces cerevisiae* or *Saccharomyces carlsbergensis* as the only agents that may turn their wort into a quality beer, and rightfully fear bacteria as the agents of beer contamination or spoilage. The following pattern of microbial development is observed in the lambic fermentation. Three to seven days after the wort has been cooled and inoculated the fermentation starts with the development of wort enteric bacteria and strains of the yeast *Kloeckera apiculata*. The pH of the wort drops from 5.1 to 4.6 because of the synthesis of acetic and lactic acids. After three to four weeks these organisms are overgrown by strains of *Saccharomyces cerevisiae* and *Saccharomyces bayanus*. These are responsible for the main alcoholic fermentation, which lasts three to four months.

A strong bacterial activity is observed next. Strains of *Pediococcus damnosus*, a lactic acid bacterium, take over the fermentation. These organisms cause a five-fold increase in lactic acid concentration and a large pH drop. They may also cause "ropiness." At this stage the presence of air in the casks may favor the growth of acetic acid bacteria of the genus *Acetomonas* and result in beer spoilage.

After eight months, a new population of yeast cells is found in the lambic. These are strains of *Brettanomyces bruxellensis* and *Brettanomyces lambicus*. They further reduce the residual extract and give the lambic its unique flavor. Oxidative yeasts of the genera *Candida*, *Cryptococcus*, *Torulaspora* and *Pichia* also may be detected after the main fermentation and may cause the formation of a protective film on the beer surface.

Lambics of different ages are then blended, and fruit is sometimes added to make a variety of lambic products. By blending young and old lambics and allowing a secondary fermentation in the bottle, as in the making of Champagne, a beer called *gueuze* is produced. The secondary fermentation is possible because young (one-year-old) lambic still contains some fermentable extract.

Secondary fermentation takes about a year. When cherries, raspberries or even grapes are macerated with the blend of lambics, the resulting beers are called *kriek*, *framboise* or *muscat*. A sweet beer called *faro* is obtained by blending lambics from high- and low-gravity worts and adding candy sugar.

FRED ECKHARDT

The Hybrid Styles

Some Notes on Their Fermentation and Formulation

What happens when you use the "right" yeast under the "wrong" conditions? Some very interesting traditional beers.

The hybrid styles (Altbier, Kölschbier, sparkling lager ale, steam beer and other common beers*) are somewhat of a mystery to the homebrewer. Some call for special yeasts, and others for specialized fermenting arrangements. Some of these brews were mysterious because little was written about them in English. Today, most of the brewing industry's secrets have been melted down into the common knowledge of homebrewing. Here then, are a few more words to dispel what may still be mysterious to some brewers.

Altbier

These top-fermented beers range in color from deep amber to rich brown, with taste mild to assertive, and hop levels noticeable to assertive. Some dark Alts are almost brown in color from the Munich and Vienna (Gerstenmaiz) or amber malt in their makeup. Alt simply means "old," that is, top-fermented ale. Actually, these beers are fermented warm in the fashion of ales, then aged cold as lager beers (14 to 40 days). Altbier may have a portion of wheat malt in its makeup. This is usually in the neighborhood of 10 to 15 percent (Düsseldorf), but **Pinkus Alt** (Munster) has about 40 percent wheat malt. Typical ingredient formulas include 2-row Bohemian-type malt, light and dark Munich and/or caramel malt, dextrin malt and perhaps a touch of black malt. Original extract gravity is 1.044 to 48. Alcohol is 4.5 to 5 percent by volume. Final beer gravity is around 1.011. International Bitterness Units (IBU) are 28 to 40 from European-style hops such as Hallertauer, Brewer's Gold, Perle, Hersbruck or Tettnanger. Color is 18 to 26 SRM (Standard Reference Method).

Let's look at some commercial examples of this beer style:

Pinkus Alt (West Germany) :
OG 1.045 alc 4.8% v/v
FG 1.011 IBU ~25
color ~22 SRM

Weihenstephan Alt (West Germany):
OG 1.040 alc 4.9% v/v
FG 1.011 IBU 27
color 22 SRM

Widmer Alt (Oregon):
OG 1.047 alc 4.7% v/v
FG 1.010 IBU 45
color ~26 SRM

Within the parameters of gravity, color and bitterness, these could well be ales in the British tradition. Features that make them different are:

- German-type malts used in water of 250 to 300 ppm hardness; traditionally a decoction mash or at least an upward step infusion is desirable with a protein rest, etc.
- The use of wheat malt in some Alts.
- The yeast strain.
- The fermenting and aging system.

Alt Yeast. Wyeast Labs of Hood River, Ore., offer an Alt strain that may be purchased from your local supplier or from many of the mail-order suppliers across the country. There may be others in various yeast banks we have access to. One also could use a good English dry yeast such as Edme, because the fermentation method has a greater impact on this style than the yeast strain.

Managing the Ferment. English ales are fermented at cool temperatures [60 to 72 degrees F (16 to 22 degrees C)] and consumed relatively soon, whereas German Alts are fermented at 59 to 68 degrees F (15 to 20 degrees C) and then aged cold [32 to 40 degrees F (0 to 4.44 degrees C)]. The yeast is added at about 68 degrees F (20 degrees C) and the ferment takes about three days, after which it is transferred to a settling tank to separate trub and yeast and complete secondary ferment at about 59 degrees F (15 degrees C) for up to seven days.

** By "common beers" I mean any top- or bottom-fermented ale that is outside any other category.*

The beer is racked again and lagered for 14 to 40 days or even longer. The lagering temperature is about 50 to 54 degrees F (10 to 12 degrees C) or perhaps down to 41 degrees F (5 degrees C) in some cases. If possible the lagering should be under low pressure CO_2 [less than 12 psi (82 kiloPascal)]. Bottle-conditioned or kraeusened beer might have to be packaged with lager yeast either in kegs or bottles.

For a homebrewer a refrigerator is necessary to make this style of beer, and for malt-extract beers one might start with a German malt extract, some wheat malt syrup (not mandatory) and up to 15 percent caramel malt. That is about 2 pounds, 6 ounces (1.075 kg) of good English caramel malt, or U.S. 60 degree Lovibond colored crystal malt.

Kölschbier

Kölsch is blond altbier from Köln (Cologne), very pale in color, with a noticeable but not intense taste profile. Kölsch is an appellation (meaning it can only be made in that area) whose parameters are carefully defined by German law: original gravity 1.045 to 47; color 3.2 to 5.7 SRM; 16 to 34 IBU from German-type hops (Hallertauer, Perle or Spalt); water hardness 450 ppm; primary ferment about three days at 64 to 72 degrees F (18 to 22 degrees C); secondary ferment, four to seven days at 57 to 64 degrees F (14 to 18 degrees C); cold lager another 14 to 40 days, and the product must be filtered. (A German court held this was not an absolute requirement if the beer was labeled as unfiltered). Kölschbier has Vienna malt and up to 20 percent wheat malt plus the usual Plzeň type along with darker Bavarian and caramel malts in its makeup.

I have found only one commercial Kölsch in this country, but here are some examples in Cologne, West Germany:

Gaffel Kölsch
OG 1.046 alc 5% v/v
FG 1.007 IBU 31
color 2.3 SRM

Stecken Kölsch
OG 1.045 alc 4.8% v/v
FG 1.009 IBU 21
color 1.7 SRM

Sunner Kölsch
OG 1.046 alc 5% v/v
FG 1.008 IBU 21.5
color 2.3 SRM

Kölsch Yeast. I don't think the proper yeast strain is available here. It may be purchased from Weihenstephan in West Germany for over $300. Possibly the University of California-Davis has such a strain in their yeast bank, but the rest of us will have to make do. Use Edme Alt yeast.

Brewing Kölsch. Review the notes under the Altbier section for some ideas, but remember this is a pale beer, so pale 2-row malt is the major ingredient, along with some Vienna malt (now available from some suppliers), and perhaps a bit of caramel malt and wheat malt, too. The malt extract recipe might include German pale malt extract, up to two pounds Vienna malt (crushed and run through a simple infusion mash starting at 122 degrees F (50 degrees C), and up to 155 degrees F (68 degrees C). Hold it there for about two hours—don't worry, have a homebrew and relax, nothing is imperative about this. Add a dollop of 20 degree Lovibond colored caramel malt (4 ounces), and perhaps some wheat malt syrup. Remember this is not a hoppy beer.

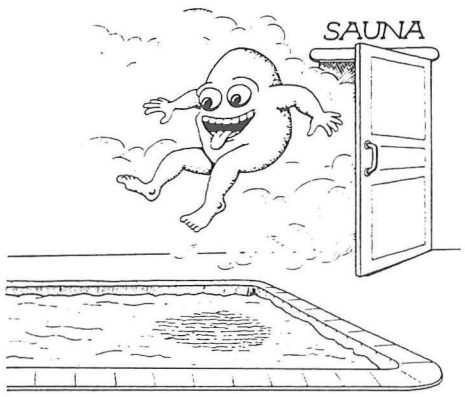
Managing the Ferment. Follow the temperature guidelines above and the suggestions in the Altbier section.

Steam Beer

Warm temperature ferments using bottom yeast produce beers with an ale character. The style was invented in California. These beers may have any taste profile, but are expected to be amber or darker in color with medium to strong alcohol, noticeable to intense hop bouquet, and rather assertive taste. The steam beer style once was made all over the West Coast, including Alaska and Idaho, and as far east as Wisconsin. Steam beers presented a darker version of what was then called "cream ale," a paler, top-fermented beer with much the same characteristics.

The original steam beers and cream ales were bottom- and top-fermented, respectively, versions of what we now call "real ale"; that is, they were fermented warm, not too well aged and served as "present-use" beers. The old, wooden beer kegs were kraeusened with fresh beer wort in the German fashion, rather than primed with sugar as the English do. Modern cream ales are bottled American lagered ales, and modern steam beer is a trademark of the Anchor Brewing Co. Ingredients: two-row or six-row American barley malt, plus up to 10 percent caramel malt and maybe some darker malts for extra color. Washington Northern Brewer hops are preferred.

California steam beer will not have been lagered cold, but may have been stored at cellar temperatures (55 degrees F or 13 degrees C) . Original extract gravity is 1.044 to 56 or so. Alcohol is 4.6 to 5.6 percent by volume. 20 to 45 IBU. Color 10 to 20 SRM. Robert Wahl and Max Henius (authors and founders of the Wahl Henius Institute, which conducted studies of beer) gave us their 1908 **California Steam Beer** recipe: Original gravity 1.044 to 50 including 33 percent adjuncts and sugars, 35 IBU, and color as amber as Munich beer, i.e., 10 to 20 SRM. **Anchor Steam™ Beer,** the only modern version of this brew



still being made, is an all-malt beer made with pale malt, 10 percent caramel malt and Washington Northern Brewer hops. In 1972 this beer had the following:

OG 1.050 alc 4.6% v/v
FG 1.014 IBU ~45
color ~14 SRM

Traditional American Common Beers

Wahl's **Kentucky Common Beer** recipe: OG 1.040 to 50, 27 IBU and 2 percent *lactobacillus* in the yeast. This was a dark beer. It is apparent that this was "sour mash" beer; that is, the mash was left to stand up to 25 hours to lend a tangy, acidic flavor.

Then there's **Pennsylvania Swankey**, flavored with anise seed or similar spices, boiled 30 minutes in the wort: 1.028 OG and 22 bitterness. A lager beer, the "swankey" is a corruption of the German "Schenk," a low-gravity present-use beer.

American Sparkling Lager-Ale

Sparkling lager-ale originated in the late 19th century as a lagered and bottled ale version of the very pale Bohemian lager beer. Today the beverage which was originally called "sparkling ale" is not found as such, but is called either "American ale" or "cream ale": i.e., very pale, cool bottom- or top-fermented beer (60 to 72 degrees F or 15.5 to 22.2 degrees C), which is cold lagered. The term "cream ale" often is used instead of sparkling ale as a name for this category. This is an incorrect use of that name, as we noted earlier in our discussion of steam beer.

Alcohol content of American sparkling lager-ale is medium, 4.4 to 5.6 percent by volume. It has minimal taste profile, minimal hopping and is lacking in hop bouquet. This style, when brewed with bottom yeast, as is commonly done, is called "bastard ale" in old brewing literature.

Some beer writers and new brewers are scornful of this style because many examples are bottom-fermented, but no matter what yeast is used, the warm ferment followed by lagering is a distinctive American contribution to brewing science. The name "American ale" is quite fitting because the technical term "ale" has long been defined in American brewing literature as more pertinent to the brewing temperature than to the choice of yeast. Some of these beers are combinations of top- and bottom-fermented brews. That is, brewed as top-fermented ale, but then kraeusened with lager wort and yeast. Traditionally, this beer type had an original gravity over 1.052, but today we find OG from 1.044 to 56, final gravity from 1.007 to 1.012, bitterness 10 to 22 IBU mostly from Washington Clusters, and color 2 to 4.4 SRM. Ingredients used are similar to American standard, but dextrose (corn sugar) or corn syrup also is used by some brewers of this beer type.

Some commercial examples:

Black Horse Ale:

OG 1.046 alc 4.9% v/v
FG 1.009 IBU ~15
color ~6.5 SRM

Carling Red Cap Ale:
OG 1.049 alc 4.9% v/v
FG 1.011 IBU ~15
color ~5.25 SRM

Labatt's 50 Ale (Canada):
OG 1.046 alc 4.9% v/v
FG 1.008 IBU ~14
color ~3.9 SRM

Weinhard's Light American Ale:
OG 1.048 alc 4.9% v/v
FG 1.012 IBU ~15
color ~5 SRM

For homebrewers to brew this style is almost an exercise in futility, because the finished product is rewarding only in a technical way. This beer type is almost impossible to brew well using malt extracts, but you might try something like this:
One 3.3-pound can hop-flavored pale malt extract. In ascending order of hoppiness use the following malt extracts to formulate your combination: Geordie American light [10 Homebrew Bittering Units (HBU)], John Bull American Beer (10 HBU), Munton & Fison American Lite (12 HBU), and Superbrau Canadian (13 HBU). Also add a second 3.3-pound can of pale malt extract (hop-flavored if you like a slightly hoppier beer). Use three packets of Red Star lager yeast, or two of Edme ale yeast. Add 1/2 to 3/4 cup corn sugar (3 to 4.5 ounces) at bottling time.

This beer will have an original gravity of 1.048, final gravity of 1.011, and 4.8 percent alcohol by volume.

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Yeast and Beer Styles
... continued from page 57

fermenting some minor sugars ale yeasts usually leave alone, and staying active down as low as 50 degrees F (10 degrees C). Flocculation is low to medium. The relative neutrality of this strain has made it one of the most popular liquid ale yeast strains. Use for light ales, classic pale ales, IPAs, porters and stouts.

Chicago Ale Yeast (M. eV. Research No. 69) also is a neutral American ale yeast. It should be used in much the same way as the Chico Ale, to which it may be closely related.

German Ale Yeast (Wyeast No. 1007) is yet another relatively clean-flavored yeast, though some complexity is present. This is a true "top-fermenting" strain, as you'll see when you use it, and flocculation is high. This, too, is a fine all-purpose yeast.

German Altbier Yeast (Wyeast No. 1338) is a first-class yeast that makes a distinct flavor contribution. The strength here is rich complexity with something of an "edge" to the flavor. Because attenuation is not as complete as with the preceding ale yeasts, you should expect slightly more body and a touch more dextrin sweetness. Fermentation is considerably slower than with many yeasts, though flocculation is high.

German Altbier Yeast (M. eV. Research No. 3) has the same "sharp" characteristic as the preceding strain, but is said to attenuate somewhat more completely. It works especially well for Kölsch-style beers, but don't ferment it warm or unwanted phenolics may result.

British Ale Yeast-Whitbread (Wyeast No. 1098, M. eV. Research No. 9) is a good, well-rounded strain. It is especially suited to the sweeter, maltier beers such as Northern-style bitters, Scotch ales and brown ales. Beers tend to be complex rather than neutral, and flocculation is medium.

British Ale Yeast (Wyeast No. 1028) is a yeast with a distinctive complexity. This is another strain that you either love or hate. The character has been described as "woody" and "minerally." Flocculation is medium and some diacetyl is produced. Use for bitters, IPAs, brown ales, porters and stouts.

Irish Stout Yeast (Wyeast No. 1084, M. eV. Research No. 4) is another complex strain with slightly less attenuation than some yeasts. A small amount of residual diacetyl complements porters and stouts quite nicely. Flocculation is medium and attenuation moderately high. Use for all stouts and porters.

Weizenbier Yeast (Wyeast No. 3056) is an excellent blend of a *Saccaromyces cerevisiae* strain with *Saccaromyces delbrueckii*. It produces tartly refreshing South German-style wheat beers in the classic style. At about four months a "clove" phenolic character becomes increasingly evident. Used in a blend rather than alone, some of *Saccaromyces delbrueckii's* more obstreperous characteristics are held in check during the normal life span of the beer.

Weizenbier Yeast (M. eV. Research No. 33) is a pure *Saccaromyces delbrueckii* strain for those desiring more intensity than they can obtain from a blend of strains.

Wine Yeast Strains

As indicated earlier, dried yeasts are only recommended for high-alcohol beers and beers consumed shortly after brewing. These wine yeast strains are probably the two best varieties for high-alcohol purposes:

Pasteur Champagne is a widely available old standby with a high alcohol tolerance. Beers and wines produced with this yeast tend to be very dry and austere.

K-1 is, as the name hints, one of the new "killer strains" of wine yeast. Such yeasts possess a factor that eliminates competing strains of wild yeast. This particular strain is noted for its neutral character.

As time passes, of course, yeast strains will come and go (and mutate). The list of those available to homebrewers in 10 or 20 years may bear little resemblance to this one, especially if genetic engineering becomes a factor. Whatever happens, I suspect the process of choosing a yeast will be much the same as now, even if the selection has changed. I also suspect that it's going to get harder and harder for us old-timers to make the next generation of homebrewers understand how bad the yeast selection "used to be back in the old days." So be it!

WINNERS CIRCLE

DAVID EDGAR

Best of 1989

Here they are—the top beers from the world's biggest and best homebrew competition ever. So pick your favorite styles and try the best examples from the 1989 National Homebrew Competition.

These are the 21 first-place beers and two first-place meads selected from an unprecedented 975 entries received this year—30 percent more than the number received last year. Never before has the competition been this heated. For example, there were 85 entries in the stouts alone and 79 in the Pilsener category.

This year the Mead category was split into Traditional Mead and Flavored Mead (melomel, pyment, cyser and metheglins). Also new this year, first-place ribbons were awarded in each of the three Pale Ale subcategories. The Best of Class (best of the three) is printed here and the first-place winners of the remaining two subcategories will be printed in Winter ***zymurgy***.

Everyone can make great homebrew with little difficulty, but many of us ask "How can I make the *best*?" Here's how.

1989 AHA National Homebrew Competition Statistics

Based on data from over 850 entries

	Entered	Passed to 2nd round	Placed 1st, 2nd, 3rd
Malt Extract	28%	27%	22%
Extract + Mash	23%	22%	18%
All–Grain	49%	51%	60%
	100%	100%	100%

	Entered	Passed to 2nd round	Placed 1st, 2nd, 3rd
Glass fermenters	77%	80%	88%
Plastic fermenters	20%	17%	6%
Stainless-steel fermenters	3%	3%	6%
	100%	100%	100%

	Entered	Passed to 2nd round	Placed 1st, 2nd, 3rd
Two-stage fermentation	72%	75%	77%
One-stage fermentation	28%	25%	23%
	100%	100%	100%

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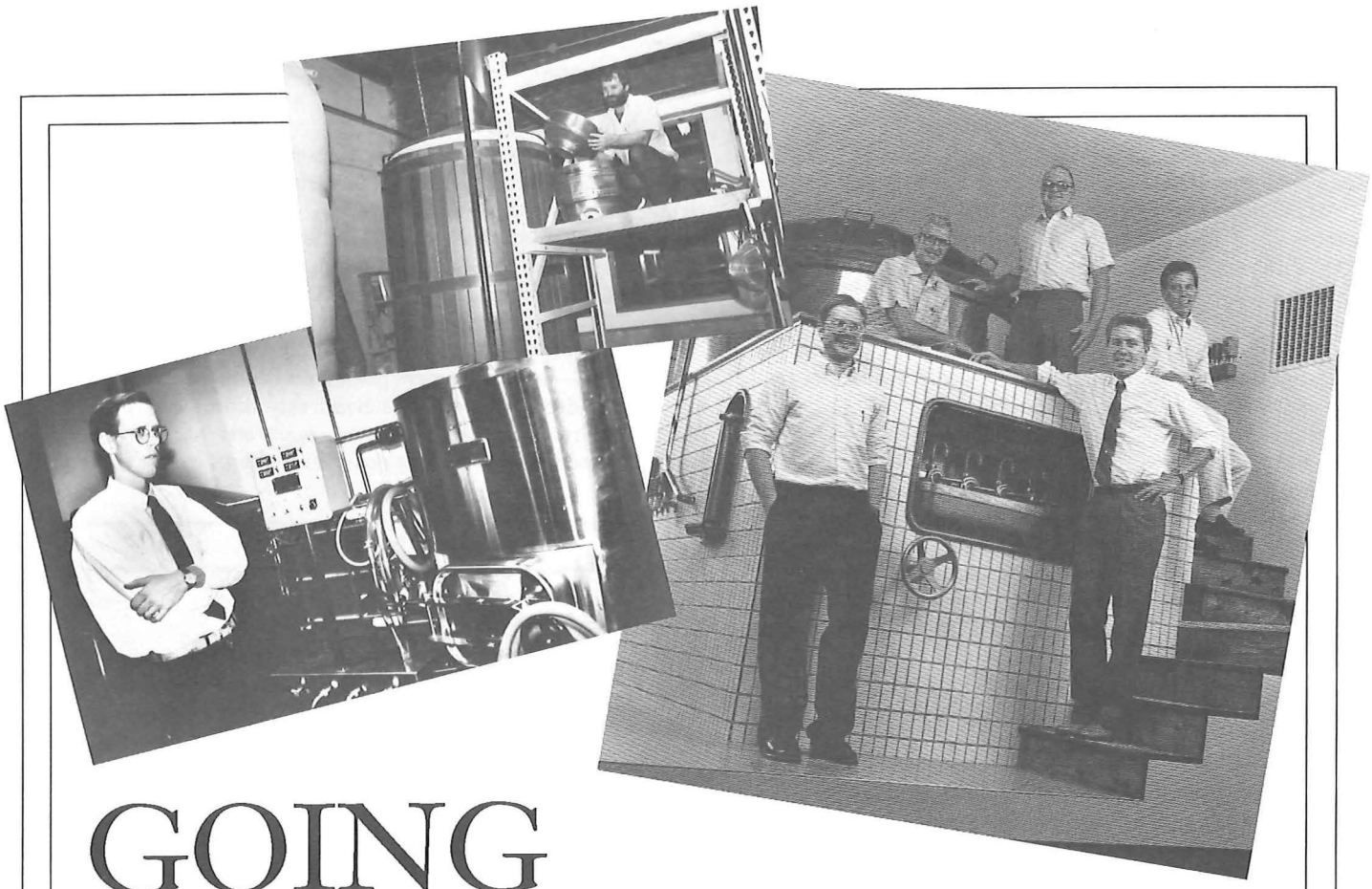
First Place
Paul Prozeller
Hamden, Connecticut

Dubbel Queensberry Framboise

Ingredients for 5 gallons

6 1/2 pounds 2-row pale ale malt
2 pounds wheat malt
1 ounce Fuggles hops (60 minutes)
1/3 ounce Challenger hops (20 minutes)
11 pints raspberries
1 teaspoon gypsum
Williams liquid German alt yeast

- Original specific gravity: 1.055
- Terminal specific gravity: 1.009
- Age when judged (since bottling): two months
- Boiling time: 60 minutes
- Duration of fermentation: three to four weeks



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The New Brewer

THE MAGAZINE FOR MICRO AND PUB-BREWERS

- Approximate temperature of fermentation: 70 degrees F (21.1 degrees C)
- Secondary fermentation: yes
- Type of fermenter: stainless steel

Brewer's specifics

Half-hour protein rest at 120 degrees F (48.8 degrees C). One-hour saccharification rest at 155 degrees F (68.3 degrees C). Boil one hour. Primed using 1 quart 1.052-gravity wort.

Judges' comments

"Appropriate aroma. Beautiful color. Excellent beer—nice and tart. Totally appropriate to style."

"Powerful raspberry aroma followed by dirty, wet-stone nuttiness. Lovely salmon-pink color. Cloudiness not inappropriate to style. Great berry tartness on entry, but wild yeast expressed more as dirtiness than sourness. Interested to know what yeast you used. Perhaps some experimenting with yeast would help, but fine job overall."

"Raspberry-grainy aroma. Slight haze; beautiful color. A nice raspberry blend flavorwise; nice lingering aftertaste. Good overall."

ALT

Great Fermentations of Santa Rosa Award
Sponsored by Great Fermentations of Santa Rosa, California

First Place
Steven Daniel
League City, Texas

Accidental Alt (or League City Ale Part II)

Ingredients for 5 gallons

7 pounds Klages malt
2 pounds German Vienna malt
1 pound German light crystal malt
1/2 pound German dark crystal malt
1 ounce Perle hops (60 minutes)
1/2 ounce Perle hops (30 minutes)
1/4 ounce German Hallertauer hops (one minute)
Wyeast No. 338 Altbier yeast
forced CO_2 to prime

- Original specific gravity: 1.054
- Terminal specific gravity: not given
- Age when judged (since bottling): not given
- Boiling time: 60 minutes
- Duration of fermentation: three weeks
- Approximate temperature of fermentation: 68 degrees F (20 degrees C)
- Secondary fermentation: none
- Type of fermenter: stainless steel

Brewer's specifics

Force-carbonated with counterpressure filler.

Judges' comments

"Sweet, malty aroma. Nice amber color; good clarity; small head. Very malty flavor. Lacks hop balance. Smooth. Great tasting beer, no off-flavors."

"Fruity, banana-y aroma. Excellent appearance; crystal clear, tawny brown beer. OK head; slightly light in color. Very nice, full-bodied malty brew with an OK smack of hops in flavor, but could use more in beginning. An excellent-looking altbier."

"Aroma—malt and esters predominate. Appearance—very clear, deep amber; little head retention. Flavor—fruity and malty; rather thin, no apparent hop flavor. Overall—good clean beer but not enough hops."

BARLEY WINE

First Place
Clay Biberdorf
St. Charles, Missouri

Willy's Best

Ingredients for 5 gallons

11 pounds pale ale malt
4 pounds Alexander's Sun Country malt extract
3 pounds light dry malt extract
1/2 pound crystal malt
1/2 pound Munich malt
2 ounces Eroica hops (60 minutes)
2 ounces Galena hops (40 minutes)
1 ounce Hallertauer hops (five minutes)
1 ounce Hallertauer hops (dry hop)
1 ounce Tettnanger hops (dry hop)
1 ounce East Kent Golding hops (dry hop)
Brewer's Choice liquid ale yeast
Montrachet Champagne yeast

- Original specific gravity: 1.103
- Terminal specific gravity: 1.030
- Age when judged (since bottling): 14 months
- Boiling time: 60 minutes
- Duration of fermentation: one week
- Approximate temperature of fermentation: 66 degrees F (18.8 degrees C)
- Secondary fermentation: three weeks
- Type of fermenter: glass

Judges' comments

"Fruity, estery aroma, more hops than malt at first—then malty. Light brown color, hazy, great head retention. Good malt-bitterness balance. Malty, bitter finish; smooth.

A good beer although not as complex as some."

"Malty nose. Head fell quickly, but nice pinpoint carbonation. Flavor has a good malty start and the hops come through in the finish. Could be a little thicker."

"Aroma—hops, malt, slight sourness, old hops? Appearance—tawny, hazy, OK. Flavor—sweet maltiness, big hop bite! Overall—big full flavor, good recipe; something is slightly off. Try to be cleaner."

BOCK

Yakima Valley Hop Growers Trophy
Sponsored by Yakima Valley Hop Growers,
Yakima, Washington

First Place
Ronald Brubaker
Cincinnati, Ohio

Stimulator

Ingredients for 5 gallons

15 pounds lager malt
2 pounds wheat malt
1 pound toasted barley
1 pound dextrin malt
1 pound crystal malt
1 pound Munich malt
8 ounces chocolate malt
4 ounces black patent malt
3 1/2 ounces Hallertauer hops (boil)
1/2 ounce Hallertauer hops (finish)
2 1/2 teaspoons gypsum
2 packets Arauner German lager yeast
3/4 cup corn sugar to prime

- Original specific gravity: 1.078
- Terminal specific gravity: 1.020
- Age when judged (since bottling): 11 months
- Boiling time: 60 minutes
- Duration of fermentation: 18 weeks
- Approximate temperature of fermentation: 36 degrees F (2.2 degrees C)
- Secondary fermentation: 17 weeks
- Type of fermenter: glass

Brewer's specifics

Mix crushed grains with gypsum and 4 gallons water at 130 degrees F (54.4 degrees C). Stabilize at 120 degrees F (48.8 degrees C) and proceed with 30-minute protein rest. Add 1 1/2 gallons boiling water and heat to 150 degrees F (65.5 degrees C). Hold 15 to 20 minutes. Add heat to raise temperature to approximately 160 degrees F (71.1 degrees C). Hold until conversion is complete (30 to 40 minutes). Sparge with 4 gallons of 170 degree F (76.6 degrees C) water using "Zapap" (plastic double-bucket type) lauter-tun. Boil one hour.

Judges' comments

"Sweet malty aroma; slight phenolic background. Color OK, clarity OK, good head retention. Good hops-malt balance; both come through. Good clean aftertaste. Good technique, all components manifest themselves in proper proportions."

"Aroma—very pleasant. Appearance—a little too dark; great carbonation. Flavor—I am satisfied, I love the balance. Overall—you have done your 'home' work well."

"Nice aroma. A little too dark; good creamy head. Good malt flavor; nice alcohol content. I really like this. It's a bit too dark."

BROWN ALE

Premier Malt Brown Ale Award Champion
Sponsored by Premier Malt Products,
Grosse Pointe, Michigan

First Place
Thad Smith
San Francisco, California

Smith 'n' Heller

Ingredients for 5 gallons

6 pounds American pale malt
5 pounds British pale malt
1 pound crystal malt
1/2 pound Munich malt
4 ounces wheat
1 ounce Kent Golding hops (60 minutes)
1 ounce Kent Golding hops (30 minutes)
2 ounces Cascade hops (eight minutes)
2 ounces Cascade hops (dry hop in secondary)
1 teaspoon salt
1/2 teaspoon gypsum
1/4 teaspoon citric acid
1/4 teaspoon Irish moss
Wyeast Chico Ale liquid yeast
2/3 cup corn sugar to prime

- Original specific gravity: 1.060
- Terminal specific gravity: 1.020
- Age when judged (since bottling): four months
- Boiling time: 60 minutes
- Duration of fermentation: three weeks
- Approximate temperature of fermentation: 85 degrees F (29.4 degrees C)
- Secondary fermentation: one week
- Type of fermenter: glass

Brewer's specifics

Step mash: 20 minutes at 110 degrees F (43.3 degrees C), 20 minutes at 125 degrees F (51.7 degrees C), 20 minutes at 135 degrees F (57.2 degrees C), 20 minutes at 150 degrees F (65.5 degrees C). Base final temperature after conversion 175 degrees F (79.4 degrees C).

Judges' comments

"Good balance in aroma; slightly hoppy. Good color and head. Good balance of flavor. The best so far."

"Aroma—lacking; needs malt. Appearance—good. Flavor—good balance and conditioning. Overall—nice beer!"

"Aroma—hops and malt very good. Appearance—excellent color, brilliant clarity, good head retention. Flavor—very good malt; very good to excellent hops; very good balance; good conditioning. Smooth, not lingering aftertaste."

CONTINENTAL DARK

Dave Line Memorial Trophy
Sponsored by Crosby & Baker, Westport, Massachusetts

First Place
Ross Herrold
La Porte, Indiana

Lady of the Morning

Ingredients for 5 gallons

4 pounds Alexander's pale malt syrup
2 pounds dark diastatic malt extract
1/2 pound crystal malt
1 ounce Hallertauer hops (60 minutes)
1/2 ounce Cascade hops (60 minutes)
1 ounce Hallertauer hops (30 minutes)
1/2 ounce Willamette hops (30 minutes)
1 ounce Hallertauer hops (one minute)
Wyeast Pilsener lager liquid yeast
3/4 cup dextrose to prime

- Original specific gravity: not given
- Terminal specific gravity: 1.013
- Age when judged (since bottling): four months
- Boiling time: 60 minutes
- Duration of fermentation: seven weeks
- Approximate temperature of fermentation: 50 degrees F (10 degrees C)
- Secondary fermentation: six weeks at 30 to 40 degrees F (-1.1 to 4.4 degrees C)
- Type of fermenter: glass

Brewer's specifics

Top-up water preboiled and prechilled.

Judges' comments

"Orange-pineapple aroma with hoppy backdrop. Perfect color; good clarity. Nice creamy head. Chocolate tones overtaken by gassiness, aggressive carbonation. Nice creaminess. Midtaste falls off at finish."

"Lovely, balanced aroma (some yeast here). Excellent-looking beer. Dry flavor. Needs more of everything (especially malt). Clean, no fermentation flaws, just needs more."

"Slightly fruity aroma; nice malt, hops OK. Good appearance. Flavor slightly diacetyl, slightly fruity. Needs hops; balance OK, slightly sharp, aftertaste fades fast. A good beer, but thin. Tastes a bit old and slightly fruity. Could call it continental dark *dry*."

CREAM ALE

The Wine Works Trophy
Sponsored by The Wine Works, Denver, Colorado

First Place
Rodney Howard
Oakley, California

Colby's Cream Ale

Ingredients for 6 gallons

8 1/2 pounds pale malt
1/2 pound Munich malt
1/3 ounce Eroica hop pellets (60 minutes)
1/3 ounce Eroica hop pellets (45 minutes)
1/3 ounce Galena hop pellets (30 minutes)
1/3 ounce Galena hop pellets (15 minutes)
1 ounce Fuggles hops (finish)
1 ounce Tettnanger hops (dry hop)
1/2 pound flaked rice
1 packet Whitbread lager yeast
forced CO_2 to prime

- Original specific gravity: 1.050
- Terminal specific gravity: not given
- Age when judged (since bottling): five months
- Boiling time: 60 minutes
- Duration of fermentation: four weeks
- Approximate temperature of fermentation: 70 degrees F (21.1 degrees C)
- Secondary fermentation: three weeks at 45 degrees F (7.2 degrees C)
- Type of fermenter: glass

Brewer's specifics

Heat water to 156 degrees F (68.8 degrees C). Add grains. Reheat to 156 degrees F (68.8 degrees C) and hold for 45 minutes. Start testing for starch conversion after 15 minutes. Once conversion is complete start sparging by

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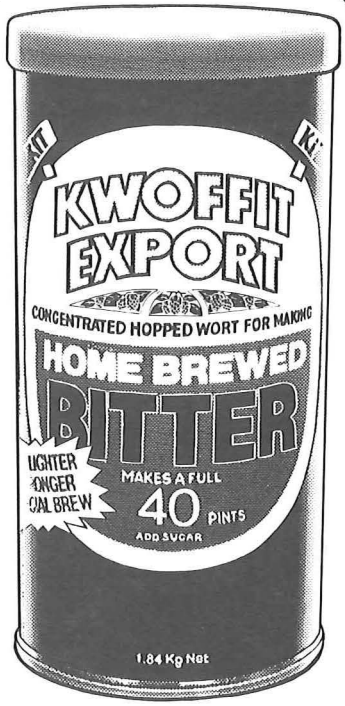


IT'S FUN!

IT'S TOP QUALITY!

KWOFFIT

Homebrewing can be a lot of fun. It has the added advantage too that you can actually save quite a lot of money. You don't have to be a heavy or even regular drinker to appreciate the difference between what your homebrew will cost and the price you'd pay in bars. But a word of caution. Make sure the quality of your beer is good. Many homebrew kits call for the use of large quantities of sugar which 'cheapens' the beer and delays fermentation, increasing the danger of 'wild yeast' contamination which ruins the beer. Avoid such kits. Use Kwoffit and a brew a fine quality real beer. That way you'll enjoy the savings you make!

Available from your local homebrew retailer. Kwoffit homebrew kits are made by Itona Products Limited, Leyland Mill Lane, Wigan, England and imported into the US by BIERHAUS INTERNATIONAL INC., 3721 West 12th Street, Erie, PA 16505 and WINES INC., 1340 Home Avenue, Suites H-L, Akron, OH 44310.

filling sparge vessel with 172-degree-F (77.7-degree-C) water 1 inch above false bottom. Add grains and wort until full. Recirculate wort until clear. Flow wort into boiler until wort in sparge is 2 inches above a level grain bed. Start the flame on the boiler. Slowly start the flow of 172-degree-F (77.7-degree-C) water over the grain bed until the specific gravity of the wort exiting the vessel is 1.008 or less. Boil. Ferment at 65 degrees F (18.3 degrees C).

Begin secondary fermentation at 50 degrees F (10 degrees C), drop temperature no more than 5 degrees F (-15 degrees C) per day. Age at 41 degrees F (5 degrees C) for three weeks.

Judges' comments

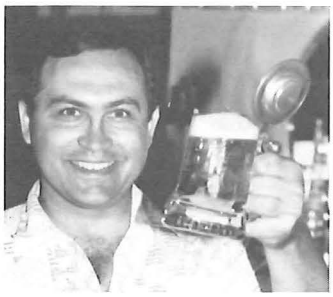
"Clean, light, fruity nose. Dense, fine head, full bead, distinct haze. Malty and corny character, appropriate light hoppy aftertaste. Slight astringency. Very close to Genesee! Excellent."

"Corny aroma, slight medicinal character. Yellow color, slight haze, good head. Corny start with a slightly malty finish. Good hop balance. Good example of a cream ale, good balance, clean finish."

"Lightly fruity aroma; innocuous aroma typical for style; no off-aromas noted. Creamy white head; good clarity and color; nice beading. Fruity-hoppy flavor; slightly sour and bitter in the finish; light body; full carbonation. This is a very good ale. The appearance is excellent. The beer is slightly overhopped and the finish is a little sour, marring what would otherwise be excellent."

EXPORT

DeFalco Wine & House Beer Trophy
Sponsored by DeFalco Wine & House Beer, Dallas, Texas



First Place
Todd Hanson
Sheboygan, Wisconsin

Reagan Knew

Ingredients for 10 gallons

17 pounds Schreier two-row pale malt
1 1/3 pounds Munich malt
2/3 pound wheat malt
1/3 pound caramel malt (40 degree Lovibond)
3/8 ounce Northern Brewer (90 minutes)
1/2 ounce Hallertauer (60 minutes)
3/8 ounce Northern Brewer (60 minutes)
3/8 ounce Hallertauer (30 minutes)
3/8 ounce Tettnanger (30 minutes)
1/2 ounce Hallertauer (finish)
1/4 ounce Tettnanger (finish)
1/4 ounce Cascade (finish)
1 ounce gypsum (for 25 gallons soft water)
Red Star lager yeast
forced CO_2 to prime

- Original specific gravity: 1.054
- Terminal specific gravity: 1.022
- Age when judged (since bottling): two months
- Boiling time: 120 minutes
- Duration of fermentation: seven weeks
- Approximate temperature of fermentation: 52 degrees F (11.1 degrees C)
- Secondary fermentation: five weeks
- Type of fermenter: glass

Brewer's specifics

Mash: protein rest at 122 degrees F (50 degrees C) for 45 minutes; boost to 155 to 156 degrees F (68.3 to 68.8 degrees C) for 16 minutes; rest at 155 to 156 degrees F (68.3 to 68.8 degrees C) for 35 minutes; boost to 170 degrees F (76.6 degrees C) for eight minutes. Sparge: 2 3/4 hours; wort collected to 1.003 starting gravity.

Judges' comments

"Excellent hoppy aroma, no skunkiness. Very good appearance; minimal head retention. Good body, clean taste. Excellent, best yet. Excellent aftertaste; seems to have an English hop aroma."

"Aroma — nice and clean. Appearance — filtered and clear. Flavor — a little too much like an ale. Overall — very nice; well-made."

"Great clarity; weak on head retention. Flavor on the sweet side, weak on hops. Smooth but not crisp enough. Very drinkable, very good."

FRUIT BEER

Purple Foot Trophy
Sponsored by The Purple Foot, Milwaukee, Wisconsin

First Place
David G. Hammaker
Roaring Spring, Pennsylvania

Cherry Ale

Ingredients for 5 gallons

6 pounds English light malt extract
1/2 ounce Bullion hop pellets (45 minutes)
1 ounce Hallertauer hop pellets (10 minutes)
10 pounds sweet cherries
2 packets Red Star ale yeast
3/4 cup corn sugar to prime

- Original specific gravity: not given
- Terminal specific gravity: not given
- Age when judged (since bottling): four years

- Boiling time: 60 minutes
- Duration of fermentation: 12 weeks
- Approximate temperature of fermentation: 60 degrees F (15.5 degrees C)
- Secondary fermentation: 10 weeks
- Type of fermenter: glass

Brewer's specifics

After boil, pour wort over cherries. Cool and add yeast. After two weeks, transfer to secondary.

Judges' comments

"Fabulous cherry-malt aroma. Quite clear. Bold cherry component needs time to blend with malt. Some diacetyl character but appropriate for style. Mouth-coating. Could use a bit more hops."

"A good blend of hops-malt-cherries; one aroma doesn't overpower the others. Clear; good head retention. A slight hop flavor along with the cherry tartness. Slightly acidic."

"Aroma—strong and clean. Appearance—very bright. Flavor—wonderful balance and flavor. Overall—dandy."

HERB BEER

The Home Brewery Herb Ale Award
Sponsored by The Home Brewery, Fontana, California

First Place
Mark C. Fjeld
West Valley City, Utah

Friendly Spruce Lager

Ingredients for 5 gallons

4 pounds Mountmellick light lager hopped malt extract
1/2 ounce Tettnanger hops (10 minutes)
4 pounds clover honey
2 packets Mountmellick Kit Lager yeast
1 pint jar new spruce growth
3/4 cup corn sugar to prime

- Original specific gravity: 1.036
- Terminal specific gravity: 1.004
- Age when judged (since bottling): 12 months
- Boiling time: 60 minutes
- Duration of fermentation: three weeks
- Approximate temperature of fermentation: 74 degrees F (23.3 degrees C)
- Secondary fermentation: none
- Type of fermenter: glass

Brewer's specifics

Honey added at beginning of boil. Spruce growth added with hops.

Judges' comments

"Nice fresh aroma. Spruce is apparent; very pleasant. Pretty beer; greenish tinge. Nice and clear. Good beading [of head]. Nice flavor from spruce; resiny. Sweet but not cloying—smooth. It's like Christmas trees! Very good beer."

"Spruce and honey aroma. Very clear—excellent clarity. Frothy, creamy head with good beading. Nice tang of spruce; it does taste like spruce. Well-balanced beer. Very pleasing and refreshing beer!"

"Surprising, like a walk in the woods. Sweet up front, dry finish. Very good, refreshing, crisp."

MUNICH

Wines Inc. Trophy
Sponsored by Wines Inc., Akron, Ohio

First Place
Steven Daniel
League City, Texas

League City Munich

Ingredients for 5 gallons

6 pounds lager malt
2 1/2 pounds German Vienna malt
1 pound German light crystal malt
1 cup German dark crystal malt
3/4 ounce Hallertauer hops (60 minutes)
1/2 ounce Hallertauer hops (30 minutes)
1/2 ounce Saaz hops (1 minute)
1 teaspoon gypsum
Wyeast No. 308 German lager liquid yeast
forced CO_2 to prime

- Original specific gravity: 1.052
- Terminal specific gravity: not given
- Age when judged (since bottling): not given
- Boiling time: 60 minutes
- Duration of fermentation: four weeks
- Approximate temperature of fermentation: not given
- Secondary fermentation: none
- Type of fermenter: stainless steel

Judges' comments

"Nice color and clarity. A sweet malt flavor; needs more hops for crispness. Smooth but needs more crispness."

"Clean aroma, not much of a malt or hop bouquet coming through. Good color. Excellent clarity. Head retention could be better. Slightly sweet and not a bad beer; good flavor and clean ferment."

Paul Prozeller

1989 Homebrewer of the Year

Paul Prozeller of Hamden, Conn., won the 1989 AHA Homebrewer of the Year Award with his Dubbel Queensberry Framboise. Prozeller's award-winning beer is a Belgian-style lambic specialty beer made with an all-grain recipe.

Prozeller has an all-stainless, 10-gallon gas-fired brewery that he designed himself, but even the best equipment doesn't solve all a brewer's problems. He used 25 percent malted wheat in his brew, and the mash bed fell during runoff. This is a typical problem with malted wheat. The particles are small and tend to clog the holes in the bed. He stirred the mash and re-established the bed, but it still took him three hours to run off only five gallons of wort.

Prozeller chose raspberries for two reasons: (1) they have a high citric acid content and don't oxidize as quickly as fruits such as strawberries and cherries, and (2) they are typical of Belgian Lambic beer. Prozeller has accumulated some interesting information about brewing with fruits. Because fruits

have a high dextrin content, they take longer to ferment. However, they also keep well because some of the dextrins feed the yeast strain he uses during bottle conditioning.

He also has discovered that waiting until the secondary fermentation to add fruit is the way to maximize fruit flavor and aroma in a beer. The essence of the raspberry is "locked up" in higher alcohols. These aromatic qualities are very volatile and evaporate quickly. Prozeller found that the action from CO_2 creation in primary fermentation "scrubbed" the aroma out of his beer. "It literally goes out the airlock," he says. "During secondary fermentation the CO_2 is much less active and more fruit essence is retained in both the bouquet and the taste of the beer." Prozeller leaves his framboise in secondary fermentation for a minimum of three weeks, and finds that up to two months is beneficial.

The story of Paul Prozeller's entrance into competition is interesting. From fall 1987 through spring 1988, he worked on weekends for the Manhattan Brewing Co. in New York, just for fun. The company had a small festival of its own after that year's Great American Beer Festival, and Chris Brooks attended. Brooks is a beer critic who writes for *Food and Wine* and *Travel and Leisure* magazines. Brooks tasted one of Prozeller's homebrews and suggested that he enter one in competition.

"Up until that time, I had been a little afraid of competing. I didn't know how to go about it or what was involved," says Prozeller. His third place in a Belgian category last year inspired him to try harder this year, with obvious results.

Prozeller got involved in homebrewing in college. He says it appealed to him because, "It was an opportunity to create something of my very own—something completely individual." He'd like to pursue a career in brewing or microbrewing because he enjoys it so much. Right now he's working on building an automatic bottle washer by converting a dishwasher he purchased at a scratch-and-dent sale. Presumably he'll need lots of clean bottles when he enters next year's competition.

Editor's Note: Paul will be flown to Boulder, Colo., to brew a commercial-size batch of his winning recipe at the Boulder Brewery, sponsor of this year's brewery trip prize.

LAURA ALLBRITTEN

PALE ALE

BEST OF CLASS

Edme Centenary Trophy
Sponsored by Edme Ltd., Mistley, Manningtree, England

First Place
Norman Hardy
Seattle, Washington

Cascade Bitter (British Bitter)

Ingredients for 5 gallons
- *8 pounds Klages malt*
- *8 ounces crystal malt*
- *2 ounces Cascade hop pellets (45 minutes)*
- *1 ounce Rogers Goldings hops (simmered 15 minutes)*
- *8 ounces brown sugar*
- *2 teaspoons gypsum*
- *Wyeast No. 1028 British Ale liquid yeast*
- *2/3 cup corn sugar to prime*

- Original specific gravity: 1.046
- Terminal specific gravity: 1.013
- Age when judged (since bottling): two months
- Boiling time: 75 minutes
- Duration of fermentation: three weeks
- Approximate temperature of fermentation: 65 degrees F (18.3 degrees C)
- Secondary fermentation: 12 days
- Type of fermenter: glass

Brewer's specifics

Step-temperature mash: 132 to 136 degrees F (55.5 to 55.7 degrees C) for 60 minutes (2 1/8 gallons); 152 to 150 degrees F (66.6 to 66.5 degrees C) for 15 minutes (3 gallons); 158 to 152 degrees F (70 to 66.6 degrees C) for 55 minutes; 168 degrees F (75.5 degrees C) for 5 minutes. Sparge: 168 degrees F (75.5 degrees C) in double-bucket "Zapap"-style lauter tun.

Judges' comments

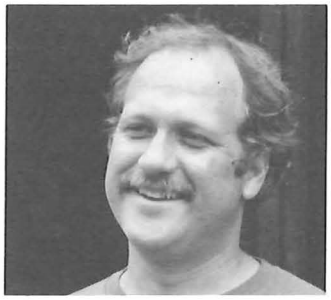
"Very nice hop aroma followed by malt. Good color. Excellent head retention—maintained for 15 minutes. Very well-balanced beer—clean. An excellent beer."

"Hop nose comes through clean with good malt aroma. If anything maybe a little more finishing hops. Color and clarity excellent—what else can I say? Flavor has great balance between malt and hops, no graininess evident. Very drinkable; no off-flavors. Well-crafted. Keep up the good brewing techniques."

"Aroma—fruity; malt and hops balanced nicely. Appearance—very clear. Flavor—excellent balance; clean. Excellent overall product. Keep up the good work."

PILSENER

Alexander's Pilsener Trophy
Sponsored by California Concentrates, Acampo, California



First Place
Eric McClary
Carson City, Nevada

Oasis Lager

Ingredients for 5 gallons
- *6 pounds 6-row lager malt*
- *1/2 pound toasted 6-row lager malt*
- *1/2 ounce Saaz hop pellets (60 minutes)*
- *1/4 ounce Saaz hop pellets (30 minutes)*
- *1/4 ounce Saaz hop pellets (finish)*
- *1 1/2 pounds long-grain rice, ground and gelatinized*
- *Wyeast No. 2035 New Ulm lager yeast*
- *1 teaspoon gelatin finings*
- *1 cup dextrose*

- Original specific gravity: 1.045
- Terminal specific gravity: 1.011
- Age when judged (since bottling): three months
- Boiling time: 60 minutes
- Duration of fermentation: 3 1/2 weeks
- Approximate temperature of fermentation: 55 degrees F (12.7 degrees C)
- Secondary fermentation: two weeks
- Type of fermenter: glass

Brewer's specifics

Toasted malt prepared by heating five minutes at 350 degrees F (176.6 degrees C).

Modified decoction mash: mash in at 120 degrees F (48.8 degrees C) for 45 minutes; add rice cooked in 1 1/2 gallons water to raise mash temperature to 135 degrees F (57.2 degrees C); add additional 1 1/2 gallons boiling water [200 degrees F (93.3 degrees C)] to raise temperature to 149 degrees F (65 degrees C) over 30-minute period. Hold 45 minutes until conversion.

Sparge at 170 degrees F (76.6 degrees C). Finishing hops steeped for 15 minutes after boil. Gelatin finings added last five days of ferment.

Judges' comments

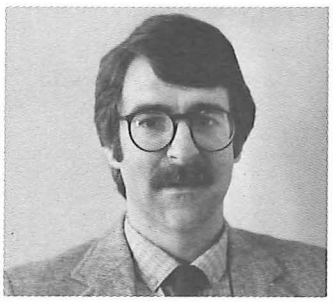
"Aroma—fine. Appearance—very nice, very clear; thick head. Flavor—slight astringency, but should fall out in short amount of time. Bitter aftertaste. Overall—very good beer."

"Good color, good clarity. Excessive head. Hop flavor appropriately light. Extremely carbonated, even for class. Aftertaste too hoppy."

"Slightly skunky-hoppy. Slight haze—color OK, head OK. Clean taste, good hop balance. Skunkiness went away after awhile."

PORTER

The Brass Corkscrew Award
Sponsored by The Brass Corkscrew, Seattle, Washington



First Place
Grant Johnston
Berkeley, California

Packer Porter

Ingredients for 5 gallons

10 pounds Klages pale malt
2 pounds light crystal malt
1/4 pound black patent malt
1/4 pound chocolate malt
1/4 pound roasted barley
1/2 ounce Chinook hops (60 minutes)
1 ounce Cascade hops (15 minutes)
1 1/3 ounces Cascade hops (finish)
1 teaspoon Irish moss
Sierra Nevada ale yeast
3/4 cup dextrose to prime

- Original specific gravity: 1.053
- Terminal specific gravity: 1.017
- Age when judged (since bottling): 3 1/2 months
- Boiling time: 60 minutes
- Duration of fermentation: three weeks
- Approximate temperature of fermentation: 60 degrees F (15.5 degrees C)
- Secondary fermentation: two weeks
- Type of fermenter: glass

Brewer's specifics

Add grains to 13 quarts 184-degree-F (84.5-degree-C) water. Stabilize to 158 degrees F (79.4 degrees C), hold for one hour. Sparge with 5 1/2 gallons 175 degrees F (79.4 degrees C) water and collect 6 1/2 gallons wort. Bring to full boil and add Chinook hops. Boil 30 minutes. Add Irish moss and boil 15 more minutes. Add 1 ounce Cascade hops and boil 15 more minutes. Turn off heat. Add 1 1/3 ounces Cascade and let soak 30 minutes.

Force cool to 80 degrees F (26.6 degrees C), pitch starter in 6 1/2-gallon carboy, and siphon wort over. Let ferment until head falls and rack to 5-gallon carboy. Condition at least four weeks.

Judges' comments

"Aroma has very slight DMS, but nice hops; a bit light on malt. Beautiful; small bubbles, long-lasting head. Clean flavor. Full and delicious. Beautiful mouth feel. Perfect marriage of malt-hops and roasted-sweet; fantastic!"

"Wonderful aroma, malt and hops well-balanced. Perfect appearance. Nice and roasty flavor. Hops well-balanced. The best so far. Great beer. What a porter should be. Would like to drink a few with you at the pub. Great porter."

"Nice malt and hops nose. Good appearance. Very nice flavor, just a little thin; needs more body. Excellent job!"

RAUCH

Jim's Homebrew Supply Shop Award
Sponsored by Jim's Homebrew Supply Shop, Spokane, Washington

First Place
Jeffrey Sternfeld
Santa Rosa, California

Cerveza Ahumar

Ingredients for 3 gallons

2 pounds mesquite-smoked Klages malt
2 pounds Klages malt
1 1/2 pounds Munich malt
1/2 pound crystal malt (40 degrees Lovibond)
1/2 pound cara-pils malt
1/3 ounce Hallertauer hops (60 minutes)
2/3 ounce Hallertauer hops (30 minutes)
1/2 ounce Spalz hops (30 minutes)
1/2 tablespoon Irish moss
1/2 teaspoon calcium sulfate
Whitbread ale yeast
3 ounces corn sugar to prime
6 ounces lactose to prime

- Original specific gravity: 1.045
- Terminal specific gravity: not given
- Age when judged (since bottling): three months
- Boiling time: 90 minutes
- Duration of fermentation: eight days
- Approximate temperature of fermentation: 60 degrees F (15.5 degrees C)
- Secondary fermentation: none
- Type of fermenter: glass

Brewer's specifics

Smoke 2 pounds malt in kettle barbecue with mesquite smoking chips.

Mash grains in 7 quarts water (with calcium sulfate added) at 158 to 160 degrees F (70 to 71.1 degrees C) for 90 minutes. Raise temperature to 170 degrees F (76.6 degrees C); rest five minutes. Sparge with 3.5 gallons water at 185 degrees F (85 degrees C).

Boil: 30 minutes with Irish moss, 30 minutes with 1/3 ounce Hallertauer hops, and 30 minutes with 2/3 ounce Hallertauer and Spalz hops. Cool wort and pitch yeast in five-gallon carboy.

Ferment eight days at 60 degrees F (15.5 degrees C).

Lager in refrigerator two weeks. Bottle with priming sugar and 1/10 ounce Whitbread ale yeast.

Judges' comments

"Smoky aroma. Great color, good head retention. Flavor great for category. Smoke comes through real good. Very drinkable—I like it."

"Aroma—very appropriate for style. Appearance—a slight haze. Flavor—excellent. Overall—a delightful flavor, great finish."

"Smoky bouquet overpowers malt-hops. Slightly cloudy. Nice balance, good flavor."

SCOTCH ALE

Wine and Hop Shop Award
Sponsored by Wine and Hop Shop, Denver, Colorado

First Place
Ronald Page
Middletown, Connecticut

Butterscotch, aka Stone Church Ale

Ingredients for 6 gallons

3 1/3 pounds Munton & Fison amber malt extract
3 1/3 pounds John Bull light malt extract
12 pounds pale malt
6 ounces crystal malt
6 ounces Munich malt
6 ounces Vienna malt
3 ounces dextrin malt
2 ounces Cascade hops (90 minutes)
3/4 ounce Cluster hops (90 minutes)
3/4 ounce Willamette hops (90 minutes)
1/2 ounce Chinook hops (90 minutes)
2 ounces Tettnanger hops (dry hop)
Edme ale yeast
5 1/4 ounces white sugar to prime

- Original specific gravity: 1.108
- Terminal specific gravity: 1.017
- Age when judged (since bottling): 3 1/2 months
- Boiling time: 90 minutes
- Duration of fermentation: 25 weeks
- Approximate temperature of fermentation: 55 to 60 degrees
- Secondary fermentation: 3 to 5 months
- Type of fermenter: plastic primary, glass secondary

Brewer's specifics

Infusion mash. Store in secondary 3 to 5 months.

(Editor's note: The above recipe is an approximation by the brewer. Here are his notes on the actual method.)

"I make my Scotch in the fall, drawing off five gallons from a 25- or 30-gallon batch of IPA. To this five gallons I add a measured quantity of unhopped malt extract, which serves the purpose of increasing the alcoholic content, darkening the color and moving the total beer balance from the hoppy to the malty. Three to five months is the proper aging time in secondary."

Judges' comments

"Complex aroma! Good combination of fruit, malt. Head didn't last long. Nice chocolate brown color. Good initial sweetness, good fruity activity in flavor. An excellent beer! Keep up the good work."

"Malty nose not present; interesting fruity quality in nose, possibly from yeast strain. A little dark for style; nice head, but dissipated rapidly. Nice malty aftertaste that *lasts*. Hop and malt balance ideal for style; a bit of licorice flavor."

"Big nose, enough malt character and tons of stewed fruit aromas. Head falls, but generally well made. Big malt sweetness is right on, good balance with a tinge of heat. Good brew, hard to fault. It may need more time in the bottle to show its best."

SPECIALTY BEER

Buffalo Bill's Brewpub™ Award
Sponsored by Buffalo Bill's Brewpub™, Hayward, California

First Place
Victor Gottlieb
Manakin-Sabot, Virginia

Gottlieb's Victory Beer No. 11

Ingredients for 5 gallons

3 1/3 pounds Munton & Fison light malt extract
3 pounds Wines Inc. amber dry malt extract
1 1/2 cups cracked crystal malt
2 ounces Willamette hops (50 minutes)
1 ounce Cascade hops (50 minutes)
1/2 ounce Willamette hops (five minutes)
1/3 ounce Hallertauer hop pellets (five minutes)
1/3 ounce Saaz hop pellets (five minutes)
6 home-grown Chinook hop cones (five minutes)
4 1/4 pounds orange-blossom honey
1 packet Edme ale yeast
3/4 cup corn sugar

- Original specific gravity: not given
- Terminal specific gravity: not given
- Age when judged (since bottling): four months
- Boiling time: 50 minutes
- Duration of fermentation: four weeks
- Approximate temperature of fermentation: 60 degrees F (15.5 degrees C)

- Secondary fermentation: two weeks
- Type of fermenter: glass

Brewer's specifics

Heat crystal malt to boiling in 16 ounces water. Strain malt and add water to 1 1/2 gallons water. Add extract and boiling hops. Boil 50 minutes.

Turn off heat. Add honey immediately. After 10 minutes, add 1/2 ounce Willamette hops. Steep three minutes and add 1/3 ounce Hallertauer pellets. Steep two minutes and sparge.

Dry hop on eighth day. Rack to secondary at two weeks, bottle at four weeks.

Judges' comments

"Aroma—alcoholic, malty; initial hop aroma was clean. Appearance—couldn't get much better; wonderful color, clear, nice head. Flavor—very smooth; initial sweetness well-balanced with hop dryness. Overall—very drinkable; well-made beer."

"Beautiful aroma—floral, hoppy, with a slight hint of malt underneath and a tang of honey. It's a beauty—what more can I say? Quite malty. Expected a little more hop bitterness. A well-balanced beer. Send me a case! And the recipe!"

"Alcoholic [aroma], aromatic. Very good color, beading and head retention. Malty flavor with dryness bordering on caramelized. Good balance. Drinkable—a keeper—good job."

STEAM

Anchor Steam® Beer Cup
Sponsored by Anchor Brewing Co., San Francisco, California

First Place
Stephen Morelli
Portland, Oregon

Fat Brothers Original American

Ingredients for 5 gallons

7 pounds Steinbart's light malt extract syrup
8 ounces crystal malt (40 degrees Lovibond)
1 ounce Chinook (60 minutes)
1/2 ounce Cascade (60 minutes)
1 ounce Cascade (10 minutes)
Wyeast lager liquid yeast
3/4 cup dextrose

- Original specific gravity: 1.040
- Terminal specific gravity: not given
- Age when judged (since bottling): 6 1/2 months
- Boiling time: 90 minutes
- Duration of fermentation: two weeks
- Approximate temperature of fermentation: 65 degrees F (18.3 degrees C)
- Secondary fermentation: one week
- Type of fermenter: glass

Brewer's specifics

Steep crystal malt with 1 gallon water, bring to boiling point. Strain out grains. Add 1 gallon preboiled water and malt extract; boil 30 minutes. Add bittering hops; boil 50 minutes. Add finishing hops; boil 10 minutes.

Pour wort into carboy containing 2 1/2 gallons preboiled chilled water. Top off and pitch yeast. After one week rack to secondary fermenter. Bottle after another week.

Judges' comments

"Good hop aroma. No haze, good appearance. Full hop flavor and malt flavor. Very good. No off-flavors."

"Nice malty nose. Head retention is very good. Nice malt and hop balance. A bit too alcoholic. Very drinkable."

"Nice hop aroma, with some malt. A bit murky. Some sourness, but the bitterness really has my tongue in a headlock."

STOUT

Coal Black Kidney Award
Sponsored by Great Fermentations of Marin, California

First Place
Rande L. Reed
Milwaukee, Wisconsin

Fountainhead Black Magic (Imperial Stout Style)

Ingredients for 2 1/2 gallons

3 1/3 pounds Munton & Fison Old Ale kit malt extract
2 1/2 pounds Munton & Fison light dry malt extract
6 ounces black patent malt
6 ounces roasted barley
6 ounces caramel malt (40 degrees Lovibond)
1 1/2 ounces Nugget hops (60 minutes)
1/2 ounce Nugget hops (10 minutes)
1 1/2 teaspoons gypsum
1 packet Red Star Champagne yeast
2 ounces corn sugar to prime

- Original specific gravity: 1.101
- Terminal specific gravity: 1.036
- Age when judged (since bottling): four months
- Boiling time: 60 minutes
- Duration of fermentation: seven weeks
- Approximate temperature of fermentation: 70 degrees F (21.1 degrees C)
- Secondary fermentation: six weeks
- Type of fermenter: glass

Brewer's specifics

Crush grains and add to 3 quarts cold water. Slowly raise temperature to gentle simmer for 10 minutes. Sparge with 2 quarts hot water. Add to brewpot to make 3 gallons total liquid. Heat to boil and add malt extract.

Judges' comments

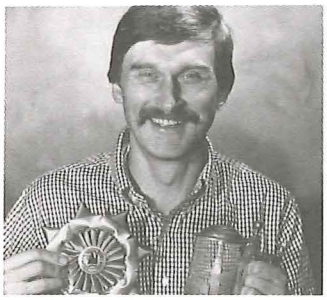
"Aroma—diacetyl and malt, OK for style; pleasant. Appearance—deep black-brown with beautiful head. Flavor—well-balanced, very rich winter warmer. Overall—give me more!"

"Caramel, butterscotch sundae aroma. Rich, dark, creamy head. Sweet but not cloying flavor; light on grain. I enjoyed this brew; it was balanced, strong, inviting."

"Nice aroma. Good head and color. Full of flavor. Definitely a winter warmer in good balance."

VIENNA

Frank H. Steinbart Memorial Award
Sponsored by F.H. Steinbart, Portland, Oregon



First Place
Charlie Olchowski
Greenfield,
Massachusetts

Does Ek Ki?

Ingredients for 7 gallons

6 1/4 pounds Munton & Fison Lager malt
5 pounds Ireks Munich malt
1 1/2 pounds Munton & Fison cara-pils malt
1 pound Munton & Fison crystal malt
1/2 pound Ireks Vienna malt
1 3/4 ounces Tettnanger hops (boil)
3/4 ounce Hallertauer (boil)
3/4 ounces Tettnanger hops (finish)
3/8 ounce Hallertauer (finish)
Wyeast No. 2308 liquid yeast
3/4 cup corn sugar syrup

- Original specific gravity: 1.052
- Terminal specific gravity: 1.012
- Age when judged (since bottling): eight months
- Boiling time: 90 minutes
- Duration of fermentation: 15 weeks
- Approximate temperature of fermentation: 48 to 33 degrees F (8.8 to .5 degrees C)
- Secondary fermentation: 14 weeks
- Type of fermenter: glass

Brewer's specifics

Two-step upward infusion mash. Raise temperature to 122 degrees F (50 degrees C), hold one hour. Raise temperature to 154 degrees F (67.7 degrees C), hold one hour.

Judges' comments

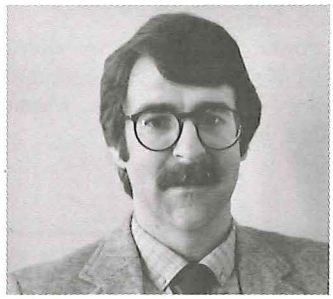
"Malty nose. Good color. Sweet malty flavor, finishes smooth. A very good beer. Slightly sweet."

"Aroma—nutty; not the true 'Munich malt' aroma. Appearance—A-1. Flavor—sweet but well-balanced for category. Overall—a fine beer; aroma and overcarbonation are my only problem."

"Malty aroma. A bit overcarbonated at opening. Malty sweet flavor, could use more bitterness to help balance it out. Nice malty sweetness yet a bit overpoweringly sweet."

WHEAT BEER

Wheat Growers Challenge Cup
Sponsored by National Association of Wheat Growers Foundation, Washington, D.C.



First Place
Grant Johnston
Berkeley, California

American Dark Wheat

Ingredients for 5 gallons

5 pounds malted wheat
4 pounds Klages pale malt
3/4 pound Munich malt (light)
1/2 pound crystal malt (40 degrees Lovibond)
2 ounces chocolate malt
2 ounces roasted barley
1 ounce Tettnanger hops (60 minutes)
1/2 ounce Hallertauer hops (30 minutes)
1/3 ounce Tettnanger (finish)
1/3 ounce Hallertauer (finish)
2 teaspoons gypsum
1/2 teaspoon Irish moss
cultured Sierra Nevada pale ale yeast
3/4 dextrose to prime

- Original specific gravity: 1.048
- Terminal specific gravity: 1.013
- Age when judged (since bottling): 3 1/2 months
- Boiling time: 60 minutes
- Duration of fermentation: four weeks
- Approximate temperature of fermentation: 50 to 55 degrees F (10 to 12.7 degrees C)
- Secondary fermentation: two weeks
- Type of fermenter: glass

Brewer's specifics

Crack all grains. Dissolve gypsum in 7 1/2 gallons soft water. Siphon 2 1/2 gallons to pot and heat to 175 degrees F (79.4 degrees C). Transfer to ice chest and add malts. Stabilize at 151 degrees F (66.1 degrees C) and mash 1 1/2 hours.

Heat remaining water to 175 degrees F (79.4 degrees C) and sparge. Collect wort and bring to full boil. Add 1 ounce Tettnanger; boil 30 minutes. Add 1/2 ounce Hallertauer and Irish moss; boil 30 minutes.

Add finishing hops and let steep (covered) for 15 minutes. Strain to primary and force cool to 80 degrees F (26.6 degrees C). Aerate wort and pitch yeast starter. Ferment; skim as required. Rack to carboy.

Judges' comments

"Fantastic aroma! Great caramel-roasted flavors. Lots and lots of head—very clear. A truly beautiful beer. Quite enjoyable; perhaps a touch too much chocolate (or other deep-roasted malt). Delicious! Complex, clean. What more could you ask for?"

"Toasty aroma. This brew seems to have a lager yeast bubble. Great clarity. Heavy roasted grains masked any clove character. A great brew with good looks."

"Caramel malt, roasty aroma. Beautiful; excellent clarity, deep copper-amber color. No phenols at all; caramel character and roast grain flavor. Very nice beer, wheat character does not come through, however."

1989 MEADMAKER OF THE YEAR

Sponsored by Home Wine and Beer Trade Association

FLAVORED MEAD

First Place
Shelby Meyer
Tucson, Arizona

Nogales Mead (Still Mead)

Ingredients for 2 gallons

8 pounds Malcolm's Desert Mesquite honey
3/4 ounce black walnut leaves
2 teaspoons Wines Inc. yeast nutrient
2 teaspoons Wines Inc. acid blend
1/16 teaspoon Prise de Mousse Champagne liquid yeast

- Original specific gravity: not given
- Terminal specific gravity: not given
- Age when judged (since bottling): 13 months
- Boiling time: 20 minutes
- Duration of fermentation: 18 weeks
- Approximate temperature of fermentation: not given
- Secondary fermentation: 16 weeks
- Type of fermenter: glass

Judges' comments

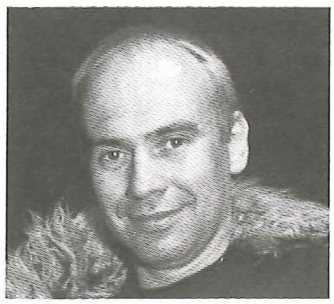
"Honey notes are evident in aroma; slight smokiness with higher alcohols. Nice, slightly brown-gold color; great clarity. Great honey flavor! Sweetness helps mask tannins; slightly bitter aftertaste. Alcoholic! Great mead. Lay it down and it will improve."

"Smells like airplane glue. Higher alcohols from high temperature fermentation. Deep golden color. Nice, sweet, full flavor. Fusel alcohols from high-temperature fermentation? Recipe is exceptionally nice. Maybe change yeast or keep temperature between 70 and 75 degrees F (21.1 and 23.8 degrees C)."

TRADITIONAL MEAD

Havill's Mazer Mead Award

Sponsored by Havill's Mazer Mead, Rangiora, New Zealand



First Place
Wayne Waananen
Denver, Colorado

Full Moon Mead (Still Mead)

Ingredients for 5 gallons

10 pounds Sue Bee clover honey
2 pounds home-grown wild honey
4 teaspoons acid blend
5 teaspoons yeast nutrient
2 packets Red Star Champagne yeast

- Original specific gravity: 1.094
- Terminal specific gravity: 1.010
- Age when judged (since bottling): 1 1/2 months
- Boiling time: 30 minutes
- Duration of fermentation: 10 months
- Approximate temperature of fermentation: 62 degrees F (16.6 degrees C)
- Secondary fermentation: yes (duration not given)
- Type of fermenter: glass and stainless steel

Judges' comments

"Nice honey aroma with a hint of fruit. Very slight haze. Honey flavor is great. Was this citrus honey? Slightly phenolic but not bad. Good still mead. I like it very much except I prefer drier. Delicate!"

"Aroma — very floral, honeyish; a little yeasty (bread-like). Appearance — extremely light. Flavor — a bit on the acidic side, but all right. Overall — very nice and clean. A bit fruity in character from acidity. Delicate."

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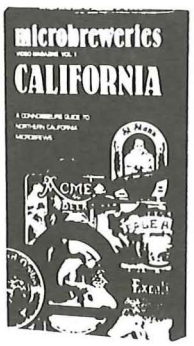

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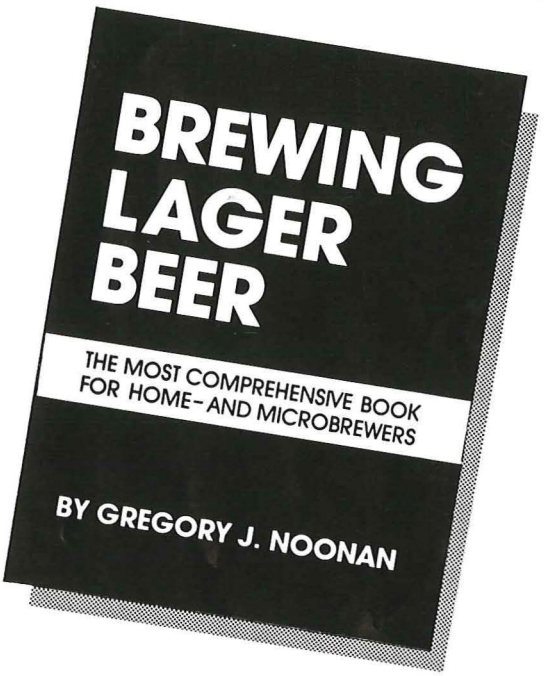
Brewing Lager Beer

By Gregory J. Noonan



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EDME MAKES A WIDE RANGE OF BEERS FOR YOU TO BREW, SO WHETHER YOU CHOOSE A PALE LAGER OR A DEEP STOUT, YOU CAN BE SURE OF A WINNER EVERY TIME.
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