Yeast Nutrients Make Fermentations Better

By Christopher White, Ph.D.

Nutritional supplements in human nutrition have become a booming business. Most are not necessary, but some can improve can improve mental and physical performance. The same can be said for brewers yeast. They do just fine by themselves. But adding the right mix of nutrients can make the yeast perform better than ever.

Does yeast get everything it needs from beer wort? The answer is … yes and no. Can it ferment wort and make beer with no extra nutrients added to all grain wort? The answer is yes. But does the yeast like that? No. You can improve your yeast performance by giving it extra nutrients.

Yeast has a complex nutritional requirement. Conversion of wort sugar to alcohol is not just one chemical reaction, as was thought in the early nineteenth century. Hundreds of chemical reactions occur inside a yeast cell. A yeast cell can be thought of as a "bag of enzymes". Each enzyme catalyzes a different chemical reaction. Each enzyme also has specific mineral requirements for optimum performance. These chemical reactions produce alcohol, flavor compounds, energy for growth, cell wall compounds, and so on. If any of these reactions are compromised, there can be an effect on yeast health and fermentation performance, which has a direct impact on flavor.

What does your yeast need? We know yeast needs sugar, and we know sugar is turned into alcohol by yeast. But yeast needs a lot more. They need amino acids to build proteins and ultimately new cells, they need vitamins and minerals to make enzymes work correctly, and they need phosphorus to create new DNA.

Exact nutrient requirements vary between ale (*Saccharomyces cerevisiae*) and lager (*Saccharomyces uvarum*), and for each strain within the species. Nutrient requirements can also vary between breweries, even when they are using the same yeast strain. It depends on your water supply, your wort composition, your brewhouse design, environmental conditions such as temperature and humidity, size of your brew, frequency of your brew, the type of beer your producing, and the season of the year. In general, yeast need an adequate supply of sugar, nitrogen, vitamins, phosphorus, and trace metals.

Nitrogen makes up approximately 10% of the dry weight of yeast cells. In brewers wort, most of the nitrogen is provided in the form of amino acids. To supplement nitrogen, ammonium sulfate is commonly used. A preferred source however, is amino acids. Yeast grow better on amino acids because amino acids are the building blocks of proteins. There are 20 different types of amino acids, and yeast can either make the amino acids they need or assimilate them from the wort. However, yeast are not capable of producing some amino acids, termed essential amino acids. Essential amino acids must be supplied by the wort. If the wort is deficient, this can create fermentation problems. Even when yeast can produce their own amino acids, it is usually better for the cell to assimilate them. For every amino acid they have to make, they create intermediary compounds that can leak out of the cell.

Valine is a classic example. Valine is an amino acid that yeast can either produce autonomously, or assimilate from the wort. An intermediate compound in valine production is acetolactate (Fig. 1). Not all of the acetolactate produced will be converted to valine, some will leak out of the cell and into the beer. This acetolactate is then chemically (not enzymaticly) converted to diacetyl in the beer. The chemical reaction is an oxidation, and high fermentation temperatures favor this reaction. Other factors that will increase diacetyl production in this phase are insufficient nutrients (e.g. the amino acid valine), which forces yeast to manufacture their own. For example, the more valine yeast produce, the more acetolactate intermediate is required, and hence the more diacetyl made. There is also an apparent strain specific phenomena occurring, because given the same conditions, different strains will produce different levels of diacetyl.

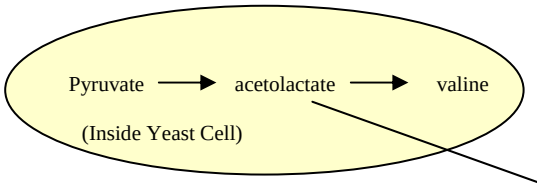


Fig.1

Acetolactate → **Diacetyl**

Vitamins are essential in many enzyme reactions. Many of the essential vitamins can not be synthesized by yeast. Typical vitamin requirements for yeast include biotin, nicotinic acid, vitamin B, and pantothenic acid. Biotin is the most important vitamin for yeast (Fig.2) It is involved in almost all enzyme reactions that create the compounds yeast are made of: proteins, DNA, carbohydrates, and fatty acids. Biotin deficiency results in slow yeast growth and stuck fermentations. Vitamins can also play an antioxidant role. For example, Vitamin C is used in some countries as an additive to eliminate any oxygen introduced during packaging.

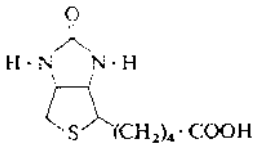


Figure 2. Biotin

Phosphorus is an essential component of deoxyribonucleic acid (DNA), as well as phospholipids within cell membranes. 3-5% of the dry cell weight material of yeast is phosphorus, most of which is stored in vacuoles inside the yeast cell. If phosphate is lacking, fermentation troubles can arise due to problems with DNA replication, which results in stuck and incomplete fermentations. Many nutrients sold to brewers are just mixtures of inorganic phosphate, which are white crystals. A more complex nutrient will contain yeast extract and therefore have a brown powder appearance.

Minerals include calcium (Ca), potassium (K), magnesium (Mg), and many more trace metal ions. Minerals are used as cofactors in catalytic enzyme reactions. They facilitate uptake of materials, and they are used in cell structural material. Ca is important for yeast flocculation, but is not thought to be required for yeast growth and fermentation. Ca salts are sometimes added to fermentations to improve flocculation. K has many functions within the cell, and can represent up to 2% of the dry cell weight of yeast cells, very high for a mineral (most are under 0.1%). If Mg is absent, yeast can not grow. Its most important role is being directly involved in ATP synthesis, the form of energy used within cells. If Mg is limited, yeast are forced to produce compounds that can compensate for some of its other functions. Mg also plays a role in preventing cell death when the concentration of ethanol builds up within the cell, and has also been shown to improve the cells ability to withstand stress[3].

Interestingly, brewers yeast has very high levels of chromium (Cr), when compared to other yeast. It is not yet known what role chromium has, but brewers yeast is used in many nutritional and cosmetic products solely for its chromium levels.

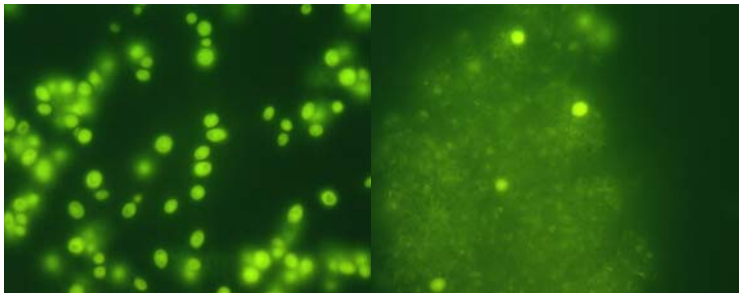
Zinc is one mineral that is often limited in brewers wort. It is needed in the micro molar (10^{-3}M) range in wort. Zinc is important in the cell cycle (reproduction), and is a cofactor for alcohol dehydrogenase, the enzyme responsible for alcohol production. Other metal ions can not substitute in place of zinc. Supplementation of zinc into brewers worts generally has the effect of speeding up fermentation, as well as preventing stuck fermentations.

Even when the wort composition of minerals is technically sufficient, the bio-availability to yeast cells is in question. Metal ions tend to chelate, that is bind to proteins or other compounds, making them unavailable to yeast. Even when metals successfully enter yeast cells, they can be chelated within the cytoplasm. This is actually a natural defense mechanism for yeast, and is useful to brewers to keep toxic metals from hurting fermentations. For example, cesium (Cs), Lithium (Li), and lead (Pb) all inhibit the ability of yeast to grow. Brewers should implement practices that reduce the loss of essential minerals.

An innovative new method of mineral delivery is Servomyces, which White Labs represents in North America. It is produced in a patented process, by which brewers yeast is grown in the presence of metal ions, including zinc and magnesium, and then dried and killed. When the dry, dead yeast (Servomyces) is added to brewery fermentations (in very minute quantities), the effect is dramatic to fermentation speed and to yeast performance/viability. The effect is much greater than with the addition of the same quantity of nutrient salts[2]. Fluorescent tests show that most of the minerals are bound within the cell wall of Servomyces (Fig.3), which may aid in preventing them from being chelated in the wort.

Fig. 3

A B



A Servomyces (Inactivated) stained with 5µM Newport Green Diacetate
B Inactivated Yeast supplemented with 1M $ZnSO_4.7H_2O$ and stained with 5µM Newport Green Diacetate
The images were prepared in the laboratory of Dr. Graeme Walker, the University of Abertay, Scotland. Permission to publish these images is gratefully acknowledged.

In the UK, use of nutrients seems to be on the rise. One English brewers supply catalog recently stated that "intensive farming techniques seem to have had the effect over the years of reducing the essential trace elements available in the wort". Water treatments are also popular in the UK, but this is more for flavor then for fermentation performance.

Summary

Can you have good fermentations, without adding extra nutrients? In general, yes. But there is so much benefit from using nutrients, that I believe their use is recommended. For example, Servomyces increases the rate of fermentation and improves viability, but are the worts used deficient in zinc, magnesium, or other nutrients? No, not always, but there is a dramatic difference when these minerals are added in the form of Servomyces. Regular use protects you from the time that you do have a fermentation problem.

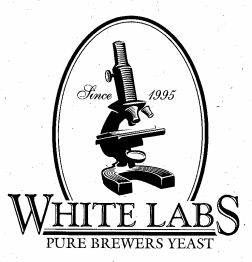
There are many stresses on yeast. The use of conical fermentors has put additional pressure stress on yeast. Many brewers are brewing high gravity beers, as they seem to garner more media attention. There is also storage stress that is applied to brewers yeast. Many craft brewers are not able to use every strain fast enough to keep the yeast active. When stored, yeast further deplete their nutrient, which needs to be compensated for in subsequent fermentations.

I think flavor may be the best argument for the use of nutrients. Although this is one area that needs to be studied further, I believe that flavor variations can be minimized with consistent addition of nutrients. Regular use of nutrient supplements can ensure more consistent fermentations. When judging beer at

competitions, such as the Great American Beer Festival, many judges are discarding beers that are not ‘clean’ enough for the style (from what I have observed). The consistent use of nutrients may put the brewer in a better position to obtain that ‘clean’ flavor time after time.

References:

1. Walker, G.M., Yeast Physiology and Biotechnology, John Wiley & Sons Ltd, 1998.
2. Mclaren, J.I., et al., Zinc Problem Solved? Brauwelt International- No.1/2001, V. 19, pgs. 60-63, 2001
3. Walker, G.M., Role of Metal Ions in Brewing Yeast Fermentation Performance. Brewing Yeast Fermentation Performance, Blackwell Science Ltd., pgs.86-91, 2000.



For more information, please contact White Labs at 888-5-YEAST-5 or info@whitelabs.com.