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QUALITY ASSURED
PERFORMANCE GUARANTEED

Feeding YEAST - for - BREWING Success!

Yeast are living organisms. Like every other, their lifespan will be greatly influenced by nutrition and care. Additional attention to the yeast can result in more consistent fermentations with richer, more complex flavors and aromas.

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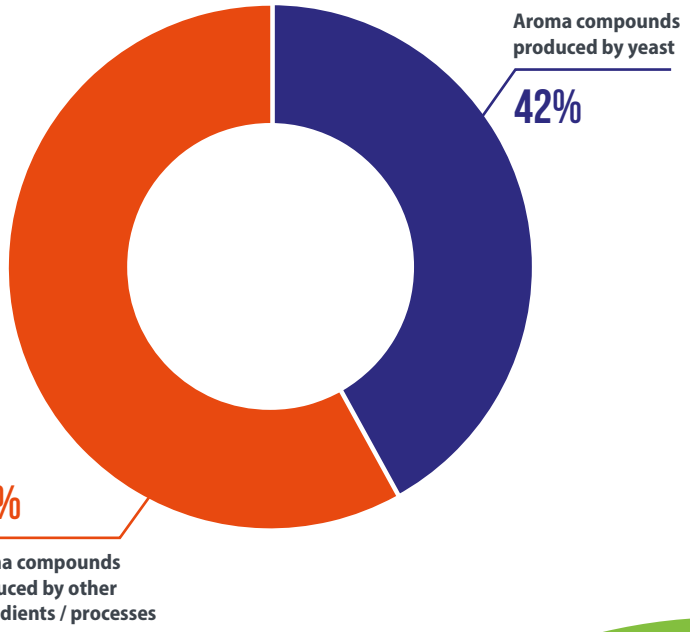
INTRODUCTION

Yeast are fundamental to the brewing process. It is thought that 950 compounds are involved in giving beer its aroma and flavor — and 400 of them are produced by yeast.[1]

Aroma is just one example of the complexity and nuance yeast contribute. Yet, the brewing process itself is not ideal for their growth and development. The presence of ethanol alcohol, carbon dioxide, and the pH of the wort can create a stressful environment.

When yeast are under stress, their performance in brewing may not be ideal and even result in off flavors or sluggish, stuck fermentations. On the other hand, offering bountiful nutrients and pleasant growing conditions can lead to consistent, reliable fermentations.



"You cannot make beer without making yeast. Very fundamentally, poor yeast nutrition equals poor beer."

- Graeme Walker, Ph.D.
Professor of Zymology from Abertay University

CONSEQUENCES OF COMMON WORT DEFICIENCIES

Ideally, an all-malt wort can provide the necessary components for a successful fermentation. However, it is common to have deficiencies or low-quality malt.

High gravity worts or high adjunct fermentations can lack the essential balance of compounds for the yeast to properly function. For example, increased extract content often is achieved by either producing a concentrated wort or adding sugar syrup to the fermentation medium. The resulting wort nutrient composition can cause yeast fermentation problems, including incomplete or slow fermentations.[2]

OXYGEN: A KEY YEAST NUTRIENT

Oxygen is not considered a nutrient for humans — but it is for yeast! Oxygen is typically required by yeast immediately after the start of fermentation. Injecting oxygen or air is not normally required for standard fermentations using active dry yeast on first pitch.

2

WARNING: SLOW FERMENTATION

Modern brewing methods may further reduce the wort's ability to supply critical nutrients, including:

- **High-gravity methods**
- **Using high levels of unmalted grains in wort production**
- **Increasing cell count during propagation**
- **Reduction of process times during fermentation[3]**

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BREWING METHODS AFFECT YEAST QUALITY

High gravity brewing requires higher sugar concentrations compared to traditional methods. This places additional stress on yeast during fermentation. Increased gravity has shown to result in:

- Lower specific growth rates
- Longer lag phases before initiation of ethanol production
- Incomplete sugar utilization
- Increases in the concentrations of ethyl acetate and isoamyl acetate in the final beer[4]

FACTORS INFLUENCING WORT DEFICIENCIES

Common deficiencies will vary based on the wort, yeast, and the intended result. In general, the wort can lack sufficient nitrogen, zinc, pantothenic acid, and biotin — or have an imbalance of magnesium to calcium. [21, 22, 23, 24] This can result in less robust yeast growth and lower enzyme production.

Supplementing with yeast food is a common practice that can help address wort deficiencies. Not all supplements are equally available to the yeast, and some supplementation options may create as many challenges as they address.

"Yeasts are like humans: The better you feed them, the better they perform. If you feed them just junk food — foods high in sugar and low protein — they will not perform as well as if you feed them a nutritionally balanced 'diet'."

- Tobias Fischborn, Ph.D.
Senior Research Scientist
at Lallemand Brewing

5 NUTRIENTS TO CONSIDER SUPPLEMENTING

In this paper, we review the five nutrients brewers may consider supplementing to improve their fermentations, which can influence the resulting product's flavor and aroma — among other characteristics.

1. NITROGEN
2. BIOTIN
3. PANTOTHENIC ACID (VITAMIN B5)
4. MAGNESIUM
5. ZINC

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NITROGEN:
THE NUTRIENT MOST LIKELY NEEDED

Without sufficient nitrogen, yeast will not grow or ferment. Nitrogen is an essential element that is needed for proper yeast nutrition. About 10% of the dry weight of yeast is comprised of nitrogen.[5] Sources of wort nitrogen are mainly amino acids, ammonium ions, and di- and tripeptides.[6]

Nitrogen availability strongly impacts the resulting product's composition and flavor.[7]

INFLUENCES BEER FLAVOR

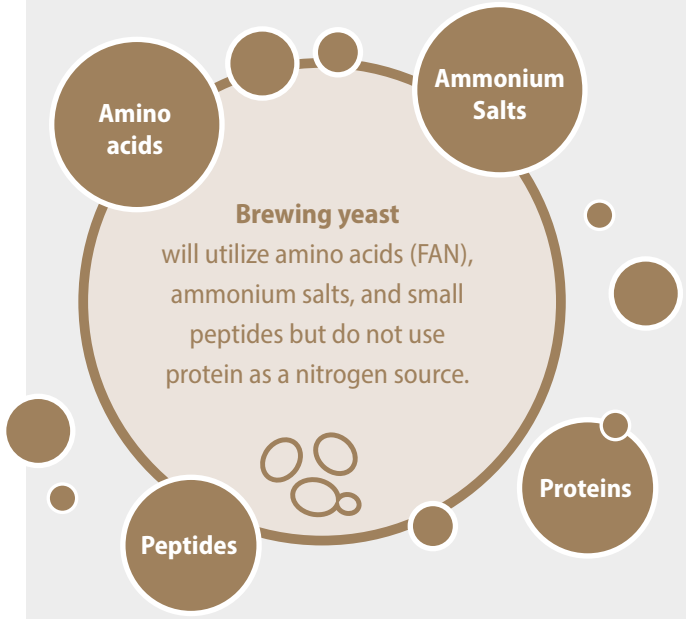
NITROGEN SUPPLEMENTATION SCENARIOS

Depending on the amount used, adjunct additions will dilute trace nutrients and nitrogen availability in the wort, making it necessary to provide supplemental nutrient additions.[1]

IDEAL LEVELS

Free amino nitrogen (FAN) refers to the organically available nitrogen that is available in wort. FAN has been regarded as the preferable indicator for predicting healthy yeast growth, viability, vitality, fermentation efficiency, and beer quality and stability.[8] Typically, FAN in wort should be around 150mg/L minimum but can range from 100-300mg/L or ppm.

NITROGEN SOURCES



WHAT IS FAN?

Free amino nitrogen (FAN) is the sum of the individual amino acids and small peptides (dipeptides and tripeptides). The majority of FAN is produced by proteolytic enzymes from malt during the malting and mashing process. There is very limited proteolytic activity from yeast. Also, a minority concentration of small peptides are produced by the hydrolytic action of extracellular yeast proteinases.[8]

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NITROGEN SUPPLEMENTATION OPTIONS

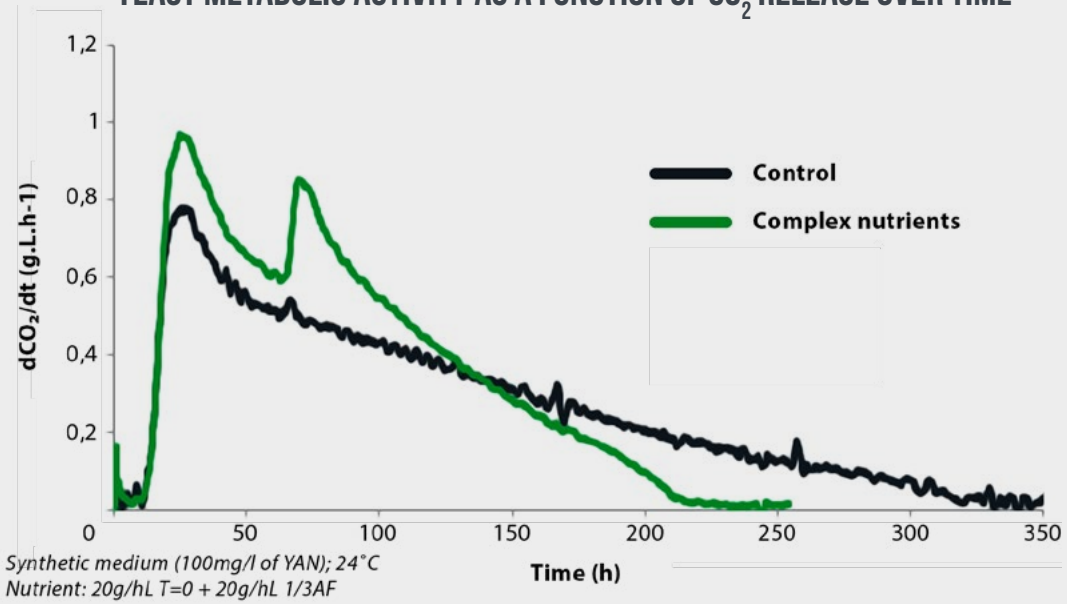
AMMONIA

Ammonia is an inorganic source of nitrogen. Common forms for supplementation are complex nutrient blends of vitamin and mineral salts including diammonium phosphate (DAP), which are ammonia salts.

The nitrogen requirement for yeast varies from one strain to another. Some yeasts need four times more nitrogen than others to ferment a deficient nitrogen medium at the same rate.[9]

Supplementing low nitrogen media with ammonia can lead to challenges. Yeast will quickly consume ammonia, leading to rapid growth. This can deplete the available nitrogen and actually cause a nitrogen deficiency. Lacking crucial nutrients, yeast will consume their own amino acids, which can lead to sulfur and various off-flavors.

YEAST METABOLIC ACTIVITY AS A FUNCTION OF CO_2 RELEASE OVER TIME



UREA

Urea provides a source of readily available nitrogen to yeast. However, it may create a chemical reaction to form ethyl carbamate or urethan(e) when combined with alcohol in the presence of heat. This compound has been shown to cause cancer in laboratory animals and is a suspected human carcinogen.[10,11]

YEAST AUTOLYSATES

Yeast autolysates are organic nutrients from the partial autolysis of yeast cells. Autolysates are produced in a similar manner to yeast extracts, but cell walls are not removed in the process. This makes them partially water soluble.

Autolysates naturally contain a good source of amino acids, vitamins, minerals, and other micronutrients. Compared to mineral salts, yeast autolysates provide a bioavailable source of nitrogen, which will be slowly taken up by yeast during fermentation. This helps avoid stressful conditions for the yeast. Yeast autolysates also can be used in brewing applications adhering to all-natural or clean standards.

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BIOTIN:

SUPPLEMENTATION REQUIRED FOR MOST BREWING APPLICATIONS

Biotin is part of the vitamin B family. It is a catalyst for multiple important reactions such as amino acid metabolism, fatty acid biosynthesis, and energy metabolism. Biotin is also an important cofactor for enzymes catalyzing carbon dioxide transfers.[12]

BIOTIN SUPPLEMENTATION SCENARIOS

Brewer's wort should be sufficient in most vitamins — except biotin. Supplementation is likely required for most brewing applications.[1]

Sugar-added fermentations almost always require supplemental vitamins, including biotin.

IDEAL LEVELS

Biotin requirements will depend on the nutrient source, brewing method, and the desired result. The nutrient requirements of yeast are different for normal, high, and very high-gravity fermentations. The bioavailability of biotin and the interactions of individual nutrients may also play a role.[3]

BIOTIN SUPPLEMENTATION OPTIONS

Yeast extracts

Yeast extracts can pose a challenge to brewing technologists due to the fluctuating physical composition of yeast extracts and their effects on fermentation processes, which can be difficult to calculate.[3] It is important to select a yeast extract from a reputable manufacturer that can guarantee consistency and quality.

Yeast autolysates

Yeast autolysates (described earlier) are also a good source of vitamins — including biotin — minerals, and other micronutrients. The cell wall contains mannoproteins, which are known to offer a favorable mouthfeel to beverages. These products can be used in all brewing applications, but the combination of nutrients yeast autolysates provide is ideal for high-sugar (low-nutrient) fermentations, such as hard seltzers.

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PANTOTHENIC ACID (B5):

AVOID OFF-FLAVORS AND STUCK FERMENTATIONS

WARNING:
SLOW FERMENTATION

Studies in winemaking show that imbalances between pantothenate levels and nitrogen can result in strong yeast mortality (more than 90%) at the beginning of the fermentation, leading to a stuck fermentation. Researchers concluded that yeast cell death was triggered by starvation for a set of micronutrients, including pantothenic acid.[7, 14]

In brewing, pantothenate deficiencies can result in an imbalance in amino acid biosynthesis, leading to excess sulfate uptake and excretion of hydrogen sulfide (H2S).[15]

PANTOTHENIC ACID SUPPLEMENTATION SCENARIOS

Strain of yeast

Some strains of *Saccharomyces cerevisiae* are pantothenate-requiring yeast, which produce hydrogen sulfide in a defined glucose-salts medium containing less than 0.1 mg of the vitamin. Hydrogen sulfide production is repressed by L-methionine but stimulated by several other amino acids even in a complete medium, although these compounds have no effect on growth.[16]

Off-flavors in brewing

A wort deficient in pantothenic acid will often get sulfuric off-flavors. Research has shown that supplementation of worts with pantothenate at 0.01 ppm suppressed hydrogen sulfide formation. Supplementation with pantothenate also decreases concentrations of sulfur dioxide (SO2) and acetaldehyde during fermentation. For some yeast and wort combinations, there is a deficiency of pantothenate, which may lead to a shortfall of coenzyme A, and this results in overproduction of acetaldehyde.[17]

IDEAL LEVELS

The proper level of pantothenate for malt worts should be between 0.45 to 0.65 mg/L.[18]

PANTOTHENIC ACID SUPPLEMENTATION OPTIONS

Yeast autolysates

Yeast autolysates can provide micronutrients, including pantothenic acid, to the brewing process.

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ZINC: A MUST-HAVE FOR PROPER FERMENTATIONS

Zinc is an essential trace element necessary for proper fermentations of yeast. Zinc is a cofactor for many reactions. Most importantly, it activates the enzyme alcohol dehydrogenase (ADH), which is the terminal enzyme in the fermentation pathway that leads to ethanol.[19]

During wort preparation, approximately 95% of zinc from malt is lost with spent grain.

Zinc deficiencies can cause stuck fermentations and flocculation problems. Supplementing zinc at sufficient levels can positively influence the metabolism and fermentation performance of brewing yeast to create:

- *Faster fermentations*
- *Better flocculation*
- *Stimulation of uptake of maltose and maltotriose*
- *Stimulation of protein synthesis and yeast growth*
- *Protection of enzymes*
- *Stabilization of protein and membrane systems*[20]

WARNING:
SLOW FERMENTATION

ZINC SUPPLEMENTATION SCENARIOS

The risk of encountering low concentrations of zinc in malt worts is very high due to zinc binding and coprecipitation with proteins during the malt wort boiling process.[19]

Sugar-added fermentations also require supplemental zinc. In addition, zinc deficiencies can be common during serial repitching of yeast.

IDEAL LEVELS

The requirement of zinc for yeast can be strain dependent, but on average the range of 0.15-0.30 mg of zinc/L is the minimum requirement.

Zinc levels less than 0.1 ppm can cause stuck fermentations and affect beer quality.

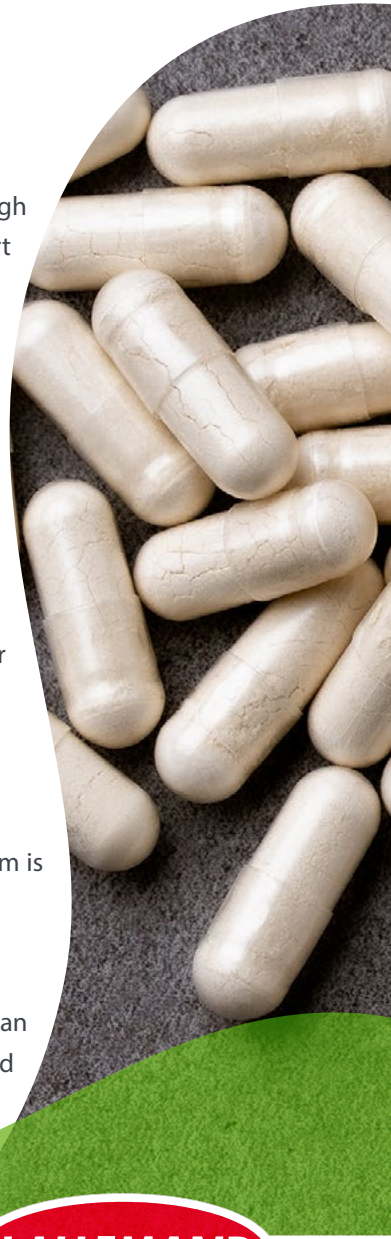
ZINC SUPPLEMENTATION OPTIONS

Zinc sulfates

Zinc sulfate is a common way to supplement this mineral. However, this form is less bioavailable than other forms and can wind up in the trub.

Zinc-enriched yeast

An active, dried yeast that has been enriched with high concentration of zinc can be added to provide a more bioavailable form of this nutrient. Specific enriched yeast brands can allow fermentation at lower temperatures for a "cleaner" taste.



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MAGNESIUM AND CALCIUM:
BALANCE FOR OPTIMAL BREWING (1/2)

Yeast sugar metabolism is strongly influenced by the concentration of mineral components, most often magnesium and calcium.[21]

Yeasts have an absolute biochemical requirement for magnesium, and this metal is an essential cofactor for the function of more than 300 enzymes. Magnesium is involved in: [21]

- *Yeast cell division and growth*
- *Mitochondrial structure and function*
- *Respirofermentative metabolism*
- *Responses to environmental stress, such as temperature and osmotic pressure* [21,22]

Calcium and magnesium act antagonistically. High calcium in the medium can suppress the active enzymes that are magnesium dependent.[23,24] Calcium mainly acts extracellularly and is essential for activity of the enzyme α-amylase and phosphate precipitation — giving calcium an important role in wort pH control and flocculation.[25, 22]

Influence of Magnesium and Calcium Variability on Yeast Fermentation Performance[24]

YEAST STRAIN	MEDIUM	MAGNESIUM (MG/L)	CALCIUM (MG/L)	MAGNESIUM TO CALCIUM	FINAL ETHANOL (%, V/V)	DIFFERENCE
Saccharomyces cerevisiae DBV 2168	White wine must	67	136	0.5	7.1	0 (control)
		1,217	114	10.7	8.7	+1.6
		47	768	0.06	4.8	-2.3
S. cerevisiae DCLM	Cane molasses	100	450	0.22	5.6	0 (control)
		190	450	0.42	6.8	+1.2
S. cerevisiae NCYC 1109	Malt wort (OG 1062)	225	140	1.6	6.0	0 (control)
		257	710	0.36	5.8	-0.2
		265	1,675	0.16	5.7	-0.3
		280	2,100	0.13	4.8	-1.2
S. cerevisiae DCLM		1,500	10,000	0.15	5.7	0 (control)
		1,500	1,000	1.5	7.7	+2.0

The table on this page summarizes the results of fermentations conducted using a variety of industrial yeast strains growing in different complex media. Although there appears to be both yeast strain and media-dependent effects, a general stimulation of fermentative activity by yeast is observed in the presence of a favorable Mg:Ca ratio.

High calcium levels are known to curtail cellular magnesium uptake and cell membrane proton-pumping ATPase activity, which is essential for nutrient translocation and cell growth.

Elevating calcium may also have an impact on premature yeast flocculation and in reduction of media pH, which may slow yeast growth and fermentation. [24]

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MAGNESIUM AND CALCIUM:
BALANCE FOR OPTIMAL BREWING (2/2)

SUPPLEMENTATION SCENARIOS

A poor quality barley crop can result in worts that are deficient in manganese, magnesium, and calcium. This can lead to lagging fermentations and poor yeast quality. Preparation of wort can also cause large differences in metal content.[22]

Some fermentation substrates, such as wine must and molasses, have magnesium-to-calcium ratios that grossly favor calcium, which can be detrimental to yeast growth.[24]

IDEAL LEVELS

The ideal balance is heavily influenced by yeast strain, medium and metal concentrations, which makes it difficult to pin down an ideal level for all brewing conditions. There is evidence that not only are the absolute amounts of calcium and magnesium important, but also the ratio of magnesium to calcium. It has been suggested that a ratio greater than two is optimum.[22]

Depending on the strain, yeast cells actively take up magnesium with a minimum requirement of 42.5 ppm (1.7 mM) with inhibition of growth occurring above 25,000 ppm (1 M).[25]

It has been shown that supplementation of both standard (12°P) and high gravity worts with Mg (500 ppm) results in: [23]

- *Higher fermentation rates*
- *Increased uptake of maltose and maltotriose*
- *Increased production of ethanol, with up to an extra 5 mL ethanol L-1 produced during high gravity fermentation when magnesium had been added as a supplement*

Calcium is required by yeast cells at a minimum concentration of 10-20 ppm (0.25-0.5 mM), with inhibition of growth occurring in excess of 1,000 ppm.[25]

CALCIUM AND MAGNESIUM SUPPLEMENTATION OPTIONS

Both tap and spring water can contain minerals. Always test water prior to brewing to build a profile that can be adjusted. Many brewers choose to use distilled water for additional control over the water profile.

Preconditioning of yeast cells with magnesium-rich wort

An alternative to wort supplementation is the preconditioning of yeast cells by propagation in a magnesium-rich wort. The magnesium-rich cells produced have greater ethanol productivity in subsequent wort fermentations than their unconditioned counterparts.[23]

Calcium supplementation

Any positive effect of calcium supplementation on yeast growth may be compromised by its antagonistic effect on magnesium uptake and function. Calcium supplementation in the wort may only be beneficial under certain circumstances.[23]

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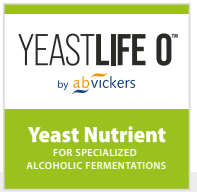
AB VICKERS SOLUTIONS

AB Vickers offers three yeast nutrients suitable for a range of alcoholic fermentations. Below you will find our reference guide, which includes basic product facts to help in selecting the nutrient best suited for your fermentation needs.

			
PRODUCT DESCRIPTION	Active yeast enriched in Zinc	Complex nutrient blend containing organic and inorganic nitrogen, minerals (ZN, Mg, Ca) and vitamins.	100% Yeast autolysates blend to provide bioavailable nitrogen, vitamins and minerals.
APPLICATION	Zinc deficient media and propagation	- Re-pitching - Low nutrient wort / high adjuncts - Stuck fermentation: high stress - Poor / variable quality malt	- Specialized alcoholic fermentation with high sugar concentration and potential low nitrogen content. - Balanced nutrition to avoid off flavor production. - Enhanced mouthfeel.
NITROGEN LEVEL	Negligible	1g/hL = 1.6 ppm	1g/hL = 0.6ppm
ZINC LEVEL	1g/hL = 0.6ppm	1g/hL = 0.028ppm	Negligible
RECOMMENDED DOSAGE RATE	1g/hL	4-10g/hL	30-250g/hL depending on application

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CONCLUSION:

GIVE YEAST PROPER NUTRITION TO GROW AND PERFORM

A balanced and healthy diet offers the same benefits for all living organisms — including yeast. With proper nutrition, brewers can experience improved fermentations, greater numbers of yeast produced, better flocculation, and improved characteristics. Understanding the needs of yeast is an important step towards expertly crafted beers.

FOR MORE INFORMATION

Contact us at **abvickers@lallemand.com**

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