GMI Certified Knowledge:
A Guide To Determining
The Right Fermenter Unit To Purchase

Introduction:

In cooperation with our scientific partners, we've prepared this purchasing guide to help you pinpoint the most ideal fermenter unit to get. In this guide, we will discuss which fermentation mode and fermenter feature/s are most suitable for specific cell types. More so, we will tackle gasses that will aid in your fermentation process, plus the recommended working volume for the cell type you're working on, and your chosen fermentation mode.

What Fermentation Mode Should You Apply?

The required fermentation mode for your lab application will depend on whether or not you need oxygen. If your applications involve oxygen, aerobic fermentation will suit your needs the most. On the other hand, you need to apply anaerobic fermentation for fermentation processes that thrive without oxygen. Another factor to be take into consideration is determining if your fermentation applications should be done per batch or continuously.

Below is a breakdown of four fermentation types that suit different purposes, and the corresponding fermenter units you should invest in to make sure you get the best outcomes from each:

Anaerobic Fermentation vs Aerobic Fermentation:

Anaerobic Fermentation:

Anaerobic fermentation refers to the fermentation mode where oxygen is absent. Alcohol fermentation used to be conducted without the involvement of oxygen in the fermentation mix. The fermentation of organic acids and lactic-acid bacteria thrive in environments containing little to no oxygen. When manufacturing goods with lactic-acid, anaerobic fermentation is applied to stabilize food color and maintain Vitamin C.

Fermenter units designed for anaerobic fermentation are much simpler than units used for aerobic fermentation, since they do not require slots for agitation and/or aeration devices. This means that if you intend to purchase a fermenter unit that is not mounted with an agitator and/or a sparger, you're good to go so long as it will be used for anaerobic fermentation purposes.

Aerobic Fermentation:

Contrary to fermentation's anaerobic nature, this fermentation mode involves the presence of oxygen inside the fermenter vessel. Oxygen, although unnecessary, speeds up the growth of yeast in alcohol production. More so, yeast cells attain higher cell density upon absorbing nutrients extracted from oxygen. Nowadays, in the production of wine and acetic acid (vinegar), oxygen is an essential component that should be added in the fermentation mix. This is because acetic vinegar, for instance, needs oxygen exposure to produce an end product that is both healthy and rich in flavor.

To effectively carry out aerobic fermentation, the fermenter unit must be mounted with an agitator to allow air dispersion, oxygen transfer, and heat transfer. In addition, the fermenter unit must also have a sparger - an aeration system device that introduces air throughout the fermenter unit.

To get a clearer grasp of the differences between aerobic and anaerobic fermentation, we have provided a table below that compares both fermentation processes in terms of oxygen usage, ATP yield, temperature requirement, and CH4 production:

	Aerobic Fermentation	**Anaerobic Fermentation**
Oxygen Usage	Aerobic Fermentation INVOLVES oxygen usage in the fermentation process.	Anaerobic fermentation DOES NOT involve oxygen usage.
Adenosine triphosphate (ATP) Yield	The ATP yield of Aerobic fermentation processes is about 38 ATP molecules.	There are no ATP yields when performing Anaerobic Fermentation processes.
Temperature	To successfully perform Aerobic Fermentation, ambient temperature is not a requirement.	Anaerobic Fermentation, on the other hand, highly requires AMBIENT temperature to yield favorable results.
Methane (CH4) Production	Methane is produced when performing anaerobic fermentation.	No methane production takes place in anaerobic fermentation.

Batch Fermentation vs Continuous Fermentation

Batch Fermentation:
Batch fermentation is a process that is conducted in separate batches. It begins by adding the raw material in the fermentation vessel, followed by introducing the required microbes to ferment the raw material. It is important to remember that this step of adding the necessary microbes for fermentation must only occur before, and not during, the fermentation process. These steps are succeeded by placing both raw materials and microbes under optimal pH and aeration levels. Once fermented, these are later on extracted from the vessel and the fermenter unit is sterilized in preparation for the next rounds of fermentation.

Continuous Fermentation:
In continuous fermentation, the process only occurs once, but runs for a long period of time. Although there are intervals from time-to-time for the purpose of introducing additional nutrients in the fermentation vessel. This allows for a more controlled fermentation outcome in terms of growth and overall output of fermented products. Metabolites, referred to as the end product of fermentation, are continuously extracted from the fermenter during these intervals.

What Are The Different Fermenter Types?

Having covered the comparison between aerobic and anaerobic fermentation, the next step is determining whether your fermentation processes will be performed at laboratory scale or industrial scale. Identifying this will better help you in choosing the ideal fermenter unit to invest in. To make sure you select the correct unit according to your applications, here's a comparison between laboratory scale and pilot scale fermenters:

Laboratory Scale Fermenters

Laboratory-scale fermenters are compact, space-saving fermenter units used for small-scale fermentation processes. Models such as the Major Science F1 Lab Scale Fermenter or the New Brunswick BioFlo 115 have fermentation vessels that are usually made of borosilicate glass with smooth, toxic-free surfaces. More so, glass fermentation vessels make it easier for the ones conducting the fermentation process to examine the vessel for results. If your fermentation processes are directed towards cell culturing, then purchasing a laboratory scale fermenter should be a priority. With its fermentation vessels made of glass, you can easily examine cell growth.

Space-saving, laboratory-scale fermenters are recommended for continuous fermentation applications, especially if directed towards cell culturing. Working with laboratory-scale fermenters is highly advised for fermentation processes aimed at the production of biomass and processes involving metabolites, such as organic and amino acids, which contribute to the

growth of organisms they're mixed with. Continuous fermentation also does not require a "cleaning" and "sterilizing" phase during the fermentation process, thus making borosilicate glass fermentation vessels sufficient.

Pilot Scale Fermenters

Pilot-scale fermenters, such as the Major Science Pilot Scale SIP Fermentation System and Winpact Pilot Production Scale Fermenter and Bioreactor SIP System, are large fermenter units used for industrial level fermentation processes. The vessels utilized by pilot-scale fermenter units are produced from stainless steel equipped with a thin hydrous oxide film throughout the vessel. This is to prevent (or at least minimize) the occurrence of corrosion.

Batch fermentation processes are more likely to require the use of large, pilot-scale fermenters. Having said this, it is of high importance for industrial-level firms involved in the production of cell biomass and products to invest in pilot-scale fermenters, which are built to perform fermentation in multiple batches. The production of edible items also makes use of pilot-scale fermenters. Being equipped with stainless steel vessels, they are shielded from contaminants that harm fermentation outcomes.

What Are The Essential Parts Of Fermenters?

Fermentation Vessel (aka Bioreactor):

All fermenter units are equipped with at least one fermentation vessel where anaerobic or aerobic fermentation processes take place. They are often times cylindrical in shape and are made of either glass or stainless steel.

Glass Fermentation Vessels

Glass fermentation vessels are commonly used in small, laboratory-scale fermenter units. Contrary to stainless-steel fermentation vessels, they are not as durable since they get damaged very easily when conducting heat. Glass enamelled fermenting vessels have gained in popularity over recent years However, they are more often used for storing beer than for actual fermentation. Brand-new glass fermentation vessels are excellent because their glass enamelled surfaces are perfectly smooth and completely sterile. Be that as it may, since these vessels are good conductors of heat, are brittle, and prone to damage, handling them requires very careful treatment.

Stainless Steel Fermentation Vessels

Stainless Steel Fermentation Vessels guarantee durability and are more protected from contamination from unwanted bacteria. They are more durable than glass vessels and are much easier to clean. Stainless steel vessels compliment batch fermentation processes that require vessels to be cleaned and sterilized per batch. Pilot-scale fermenter units like the New Brunswick BioFlo 3000, which are used for industrial level fermentation-based production, come equipped with two or more stainless steel fermentation vessels that are built to handle large-scale fermentation processes. The caveat of purchasing fermenter units with glass vessels is they are priced a bit higher than those with glass vessels.

Agitator (aka Impeller):

In fermenter units like the New Brunswick BioFlo 110, the agitation systems essentially perform two functions: mixing the fermenter's contents and maintaining a uniform, homogenous environment for all particles involved. The latter function promotes smooth oxygen, heat, and nutrient distribution, ensuring high quality product outcomes. In addition, agitators are categorized into two types: agitators with axial agitation and agitators with radial agitation. Fermenter units may either have one of the two or a combination of both. To make a smart purchasing decision on which fermenter unit to make, there must be a clear understanding of the distinct characteristics of axial and radial agitation.

Axial vs Radial Agitation

Axial Agitation

In agitators that perform axial agitation, the liquid is pushed away from the components of the fermentation process. Ultimately, axial agitation is recommended in fermentation processes involving liquids with solid particles, since they demand strong vertical currents for solid suspension or stratification. The axial flow depends on whether the agitator is placed on the left-hand or the right-hand side of the fermenter unit. If the agitator is positioned to the left-hand side, components will be pushed downward until it reaches the bottom of the fermentation vessel. Conversely, an agitator placed to the right-hand side will push components toward the top-most part of the fermenter vessel.

Radial Agitation

Unlike agitators with axial agitation, radial agitators offer low-level mixing intensity, pushing the liquid away from the axis and toward the fermenter vessel wall. The liquid being pushed away is then divided into two streams, with one going upward and the other going downward. Upon reaching the fermenter's central axis, both streams are drawn back to the agitator. Radial

agitators are widely used in fermenting cells that are not shear-sensitive, namely yeast and bacteria.

Sparger:

Fermentation processes that involve gas will require fermenter units equipped with a sparger, such as the Major Science MSF1. Also referred to as the fermenter unit's aeration system, spargers allow air to be introduced in the fermenter vessel and fuse with all components involved in the fermentation process. Ideally, spargers should be capable of eliciting large bubbles as this allows for a larger amount of oxygen to pass through. In the absence of an agitation system, a sparger may take its place, provided that the fermentation medium has low viscosity and low total solid count.

Spargers are classified into three types: porous, orifice, and nozzle. A description and comparison among three types is found below:

Porous sparger

Porous spargers are only used for fermenter units without agitated vessels. As it introduces air in the vessel, it forms bubbles that can be ten or a hundred times larger than its pore size. Non-agitated fermenters are usually equipped with porous spargers, which implies you do not want to invest in such fermenter units if your lab applications involve aerobic fermentation.

Orifice sparger

Small fermenter units with agitated vessels make use of orifice spargers. It appears as a perforated pipe positioned at the bottom of agitators and may take the form of crosses or rings.

Nozzle sparger:

If you're looking for fermenter units that prevent impellers from being flooded by air streams, invest in units equipped with a nozzle sparger. Nozzle spargers are positioned directly at the bottom of the impeller and have the lowest pressure loss than the other two spargers mentioned.

Baffle:

In fermentation, one thing you want to prevent is vortex formation. It alters the vessel's center of gravity and consumes too much power. This is why fermenters are equipped with a baffle, because its purpose is to interfere with vortex formation which often occurs in radial agitation. Baffles heighten friction levels to a point that incapacitates tangential velocities to cause the

entire liquid mass to whirl around the vessel. Aside from preventing vortex formation, baffles also improve mixing in fermentation processes with low agitating speeds and scarce oxygen input.

What Elements Do You Need To Measure & Control?

Temperature Control

The way temperature control takes place depends on the size of the fermentation unit. Normally, temperature is controlled by a 300 - 400 watt heating element. Through this, thermostatically heated liquid will surface the fermentation vessel, providing temperature control of ±0.1ºC. As a general rule, the size of heating elements should match the fermentation vessel's available space. Small heating elements made of wire are used for lab-scale fermenters, while large metallic heating elements are for industry-scale fermenter units. Some fermenter units, including the Winpact Bioreactor and Fermentor, do not require heating elements to perform temperature control; they are instead equipped with a 15-step programmable temperature controller.

Dissolved Oxygen Control

Measurement and control of dissolved oxygen in the fermentation vessel is conducted by a dissolved oxygen probe calibrated for its 0 and 100% values. Both the "0" and "100%" value pertain to the dissolved oxygen's measured value when the fermentation vessel is saturated with nitrogen purging. Nitrogen purging is defined as an industry-standard procedure that eliminates toxic, hazardous elements within the fermentation vessel and replaces it with elements that help propel favorable fermentation process outcomes. Once nitrogen purging is performed, dissolved oxygen probes are enabled to measure dissolved oxygen values, thus allowing for an easier oxygen control. In aerobic fermentation processes, if the oxygen probe determines oxygen levels to be low, it signals that more oxygen should be pumped in the fermentation vessel and/or the agitator be increased in speed to further enhance oxygen transfer.

pH Control

If the fermenter unit is to be utilized for cell culturing, you have to make sure the unit is able to perform pH measurement and control. This is because pH is a critical indicator of cell growth, metabolism, and the overall quality of the final outcome. In addition, there are a number of microorganisms that will only grow at certain pH levels. In penicillin production, for instance, the pH levels of P. chrysogenum's commercial mash should be observed in both the growing and production phases. The mash's pH level must be maintained at a range of 4.5 - 5.5 during the growing phase and should be increased to 6.8 - 7.8 once it enters the production phase by introducing sulfonic acid in the mix. Henceforth, it is encouraged that you invest in a fermenter

unit such as the New Brunswick BioFlo 115, because it allows pH measurement and control, for it will aid you in determining the needed pH level for your fermentation applications.

How Much Working Volume Do You Need?

Working volume is defined as the fraction of the total volume taken up by the medium, microbes and gas bubbles. Typically, this volume takes up 70-80% of the total fermenter volume and is measured in liters. However, this rate is subject to change depending on the foam formation rate. If the medium or fermentation has a tendency to foam, a larger headspace and smaller working volume is necessary. This is so because a larger headspace volume increases the tendency for the foam to collapse under its own weight. For example, fermentation in which high levels of foam is produced will require a headspace volume of 50% headspace volume may be required.

How Are Fermenter Units Priced?

In fermenter units, one determinant of price-setting is the unit's overall functionality. Fermenter units made for aerobic fermentation are installed with impellers and spargers, ensuring oxygen is introduced and spread throughout the vessel. Therefore, such units will definitely cost more than other units without impellers and/or spargers. The number of fermentation vessels also plays a role in adding to the unit's overall value. Industry-scale fermenter units are designed for mass-fermentation. Two or more vessels are in place to meet these types of fermentation demands. Being priced higher than single-vessel fermenters, you should be willing to allocate a larger budget when purchasing these.

GMI has a range of brand new fermenters from Winpact Scientific and Major Science. Both brands are renowned for offering top-of-the-line laboratory equipment, particularly fermenters. Their line of fermenter units perform cell culture, biotechnology and other microbial applications with sheer attention to detail. Being brand new, these units will definitely cost you more. Apart from the fermenter unit, part of what you're getting is up-to-date fermenter technology like programmable temperature controls. Should you decide to go for a more budget-friendly purchase, you may always select from GMI's line of refurbished fermenter units from New Brunswick. All these are recertified in GMI's 9001:2008 certified facilities. In-house engineers painstakingly restore these units in tip-top shape, making sure customers will not be shortchanged. Regardless of which fermenter unit you get, fair warranty periods and multi-year service agreements are included in your purchase.

To further help you in your decision-making, GMI also provides a service that allows you to rent and try various fermenter units before committing to that big purchase. This way you can, see for yourself which fermenter model would best fit your day-to-day research operations. Rest

assured all these units undergo regular maintenance and calibration, giving you the opportunity to dedicate all your attention to your fermentation applications.

If you happen to own an out-of-date, underperforming fermenter unit, you also have the option to sell your unwanted lab equipment to GMI. They can either pay you in cash or credit that may be used in purchasing new or refurbished fermenter units. In addition, you are welcome to participate in GMI's trade-in and trade-up program. This is where you can trade-in unwanted fermenters to attain a discount for a better model. You can also cosign your fermenter and other lab equipment to GMI, to help you in selling these at the best possible value.

If you're still undecided on which fermenter unit to invest on, you can always reach out to an expert for assistance. Being an industry leader in the industry of laboratory equipment distribution for over 20 years, you can assure that GMI's pool of experts will direct you to the right fermenter unit for your applications. Do not hesitate to reach us at 1-888-702-1775 or sales@gmi-inc.com should you have queries on your next fermenter purchase.