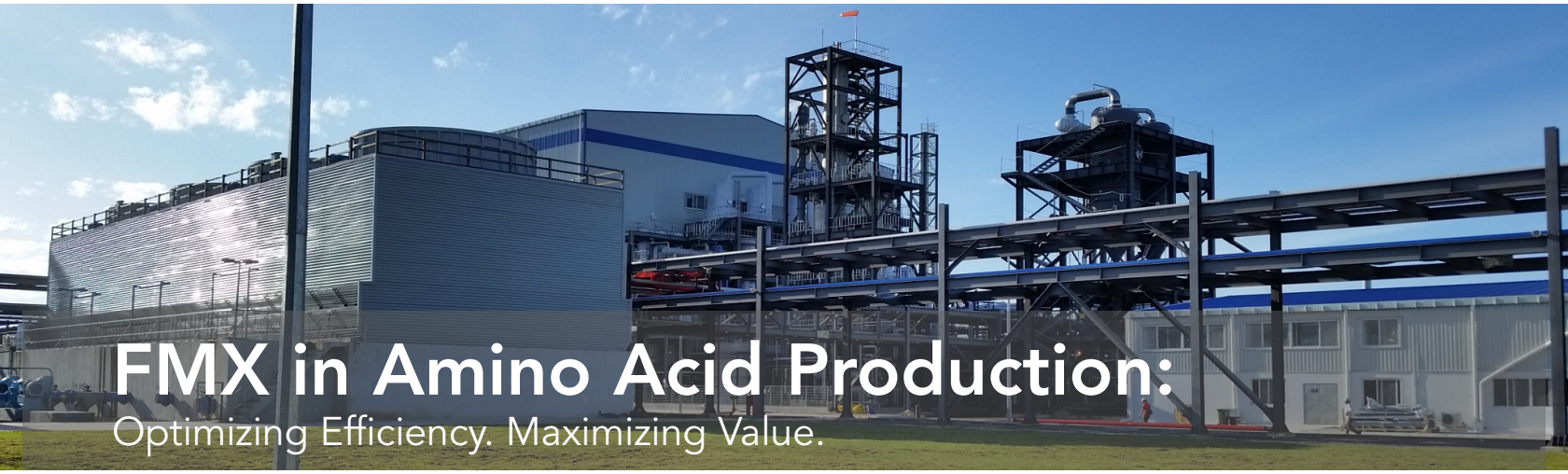


FMX in Amino Acid Production:

Optimizing Efficiency. Maximizing Value.

Industry Trends

Over the last few decades, amino acid production technology has made large strides in response to rising global demand as new applications for amino acids are continually discovered. In this progress, fermentation technology has played a crucial role, cementing fermented amino acids as the chief products of the biotechnology industry, both in volume and economic value.

Conventional Process & Challenges

Amino Acid Production with fermentation process

Most amino acid production processes follow a similar structure, beginning with fermentation and proceeding through cell separation from the fermented solution, ion exchange, evaporation, and ultimately refinement of the final product.

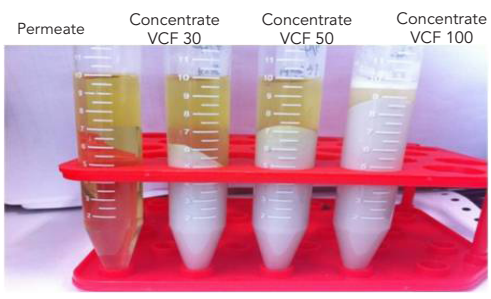
Conventional production employs decant screw or centrifugal separators for the initial stage. Unfortunately, neither the decant screw nor the centrifugal separator can achieve complete elimination of residual cells that lower the effectiveness of the ion exchange resin during later stages. Ceramic membranes, currently being used for diafiltration, experience frequent fouling issues that limit concentration efficiency or product recovery from intermediate liquid streams with high viscosity and solids content.Furthermore, the residual liquid content in permeate from diafiltration requires high energy consumption during the evaporation process.

PRIMARY CHALLENGES

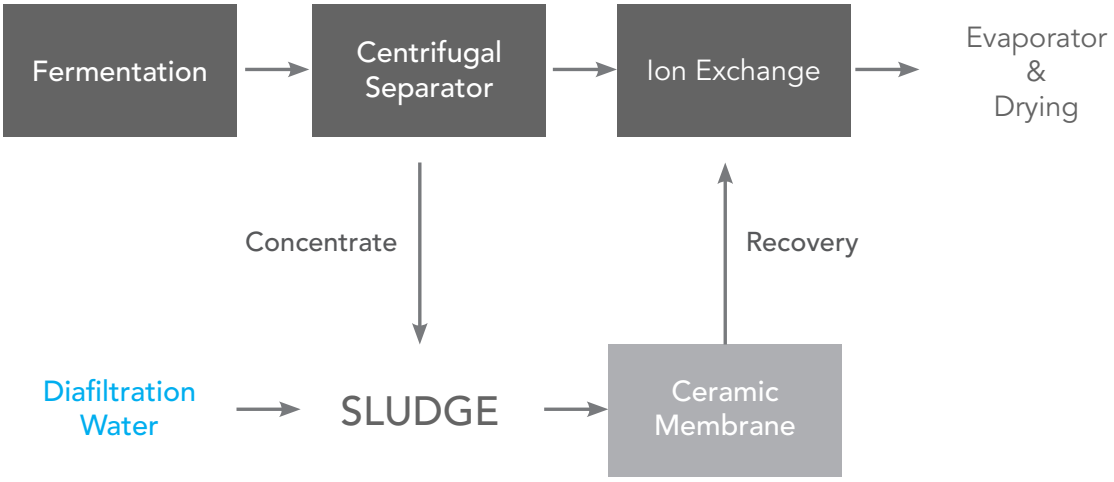
- *Incomplete separation after the decant screw and centrifugal separator stage.*
- *Frequent membrane fouling from high solids loading.*
- *High energy consumption from the drying process.*

FMX: Anti-fouling membrane filtration solutions

Amidst many competing technologies, FMX technology has proven itself to be a cost-effective solution for the high concentration and efficient recovery of amino acids: lysine, glutamine, methionine, tryptophan, and etc., uses of which range from livestock feed to improvement of taste in foods to cell regenerative ability. While standard production processes for amino acids face numerous challenges, including low recovery and concentrationw, incomplete cell separation, and membrane fouling, many of these problems can be largely alleviated by the integration or introduction of the FMX.



L-Methionine



<Conventional Amino Acid Production Process>

Higher Recovery & Concentration

In amino acid production, concentrate streams with high solids are typically treated with ceramic or hollow fiber membranes for diafiltration. When compared to these current standards, however, FMX is reliably capable of achieving higher recovery and higher concentration while requiring lower run time.

The comparison between the effects of the FMX and that of other membrane systems is clearly seen above in samples resulting from a methionine production process. The conventional membrane could achieve concentration of only VCF 40, while a ceramic membrane managed to reach VCF 60; only with the use of FMX was it possible to reach concentration of VCF 100, maximizing the amount of permeate collected. Overall, FMX was able to increase the resulting concentration 2.5 times for methionine production case.

Complete Liquid-Solid Separation

Not only does the FMX outperform existing decant screw and ceramic membrane filtration in recovery and concentration but also in achieving perfect liquid-solid separation of solids content. In particular, FMX's ability to eliminate 100% of fine solids during initial filtration promotes effectiveness further down the process train by reducing error in the subsequent ion exchange stage.

Even when applied to challenging streams with extremely high solids loading, FMX continues to delivers consistent performance because its anti-fouling vortex generator technology minimizes membrane fouling, facilitating reduction in maintenance time for maximization of production efficiency.

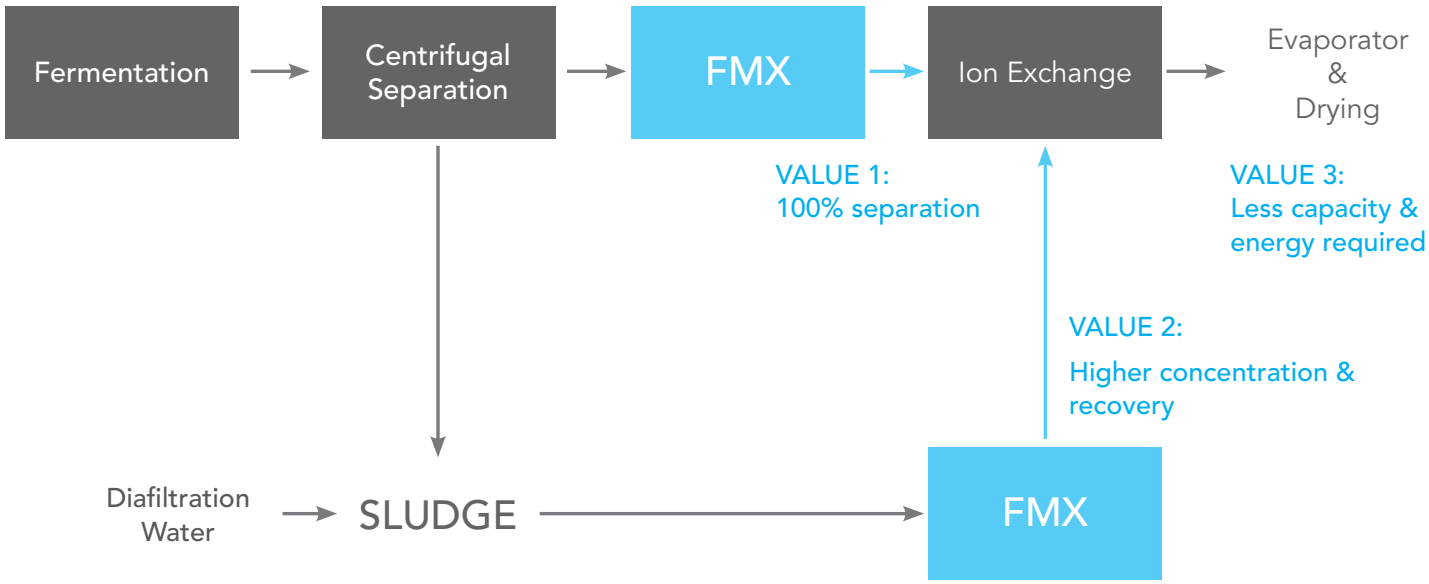
Water & Energy Savings

Due to its ability to handle such high solids loading, FMX also requires less water to be added for diafiltration than does ceramic membrane systems, thereby providing clients with savings in costs both upfront and in the backend. Integration of the FMX reduces the amount of water required for the initial diafiltration process and subsequently the capacity of the evaporation process and associated energy costs. FMX has been shown to reduce power consumption up to 30%, from 1.0kW/m^2 to 0.7kW/m^2 in the case of lysine production, while simultaneously decreasing load capacity and associated capital cost and facilities investment.

Versatile Integration into Existing Process Train

Also key is FMX's versatility as both a primary and secondary step at multiple points in the process train. While the FMX is capable of replacing the centrifugal separator in the initial step of the production process, clients can also enjoy the unique benefits from integration of FMX without modifying their existing process, increasing efficiency without interrupting or affecting current production.

As seen below, the FMX can be utilized as a side stream step to process the dense concentrate, deriving more value than the standard ceramic membrane by concentrating the result even further or by ensuring 100% liquid-solid separation by optimizing ion exchange and reducing the capacity of the drying process.



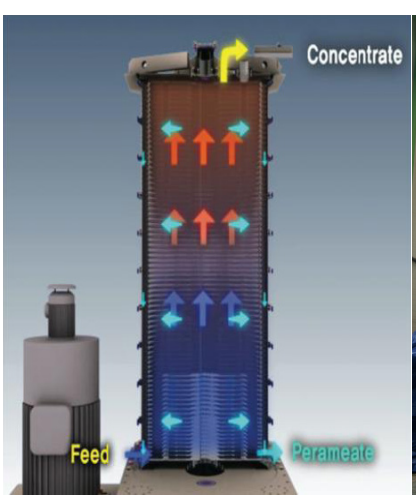
<Amino Acid Production Process with FMX>

The FMX Advantage

When applied to production of amino acids, FMX increased product purity and process efficiency across the board, minimizing the incidence of membrane fouling while reliably delivering higher concentration ratios. Thus reducing load capacity for the stage of process, FMX offers additional economic benefits through boosting efficiency of the drying and significantly reducing power consumption.

Summary of Benefits

- *Increased recovery and/or concentration.*
- *Up to 100% cell separation.*
- *Consistent water & energy savings.*
- *Integration into existing process train.*



CASE STUDY | FMX in place for L-Methionine Production

While the typical production process for Methionine results in DL-Methionine, L-Methionine has 20-40% higher relative bioavailability than DL-Methionine and is thus sold at a higher market price. In 2014, Korean biochemical company CJ Bio became the first in the world to develop a means of producing L-Methionine through a fermentation process.

Background

In planning the complex separation process necessary for this application, CJ's engineers initially chose to utilize conventional ceramic membranes to separate the target L-Methionine material from its broth. Fascinated by the test results, however, CJ integrated FMX equipment creatively as a side stream process to treat the concentrate already rejected by another membrane system in the process train.

FMX Installation

CJ's master plan used a ceramic membrane as a diafiltration process with VCF (volumetric concentration factor) target 50. Encouraged by FMX pilot tests, CJ team set its new concentration goal as VCF 100 after addition of the FMX system as a side stream process. Though it is conventionally considered quite challenging to achieve concentrates even higher than the material rejected from other membrane, the FMX system was able to meet the goal of VCF 100 through its full-scale diafiltration process.

Major Benefits: Results of FMX Integration

Commissioning completed in 2014, the integrated FMX continues in full-scale operation successfully to the present day and is expected to generate additional revenue varying up to $500,000 per month, totaling at least $3M per year.

Furthermore, associated reduction in the process water necessary for diafiltration and energy consumption for evaporation is reflected in annual savings of $500,000, with additional savings through downsizing of the pump utilized.

- *Higher concentration than ceramic membrane => Higher revenue ($3M / year)*
- *Less energy for evaporation due to less process water => Lower cost (by $500,000 / year)*
- *Less energy for pumping => Lower cost (~30%)*

Ultimately, CJ hopes to shrink multiple processes into a single FMX filtration step through potentially implementing the FMX system as a single main process to eliminate redundant dewatering steps.

What is the FMX?

FMX is a membrane filtration system specifically designed to prevent fouling, especially for applications with high solids loading. Originally developed for wastewater treatment, FMX is capable of being adapted to utilize any type of flat sheet membrane, created from a variety of materials (including ceramic and metal) and for any pore size (e.g. MF, UF, NF, LPRO). Currently, FMX is applied widely in production processes across a diverse range of industries, including chemical, biochemical, and food & beverage.