



10 ways to improve your bio-based chemical plant

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Great opportunities

Bio-based chemicals production is a rapidly growing field in the processing industry. As with most new technologies, there are both great opportunities and many pitfalls.

To be successful you first need to make the process work in a lab environment and then scale up to commercial production and make the process financially viable. The challenges you face in these two stages are very different, and to be profitable you need to overcome all of them.

A reliable partner

To make the most of your investments it is essential to partner up with an experienced equipment supplier that helps you find the optimum solutions for your plant.

All plants are different, and seemingly small details can have a big impact on plant profitability. You need to tailor each process step to your specific plant, and there are no general, one-size-fits-all solutions. That is why we always ask a lot of questions when you meet us, not just about the specific positions for our products, but about your entire plant.

At Alfa Laval we cooperate with many of the world's leading producers of bio-based chemicals, and we have extensive experience from working with similar industries such as pharmaceuticals, sugar and starch, biofuels and chemical processing.

We help you:

- Increase yield
- Reduce operating costs
- Minimize downtime and service
- Cut investment costs
- Improve product quality

Equipment and good advice

Alfa Laval offers a unique range of products for production of bio-based chemicals. We supply equipment for feedstock preparation, sugar solution pre-treatment, fermentation, microbial cell removal, concentration, purification and further processing downstream.

This white paper outlines some of our best advice, and we hope you will find it useful. Please contact us if you have any questions or if you would like to discuss possibilities for your plant.



1. Look at the big picture when designing individual process steps

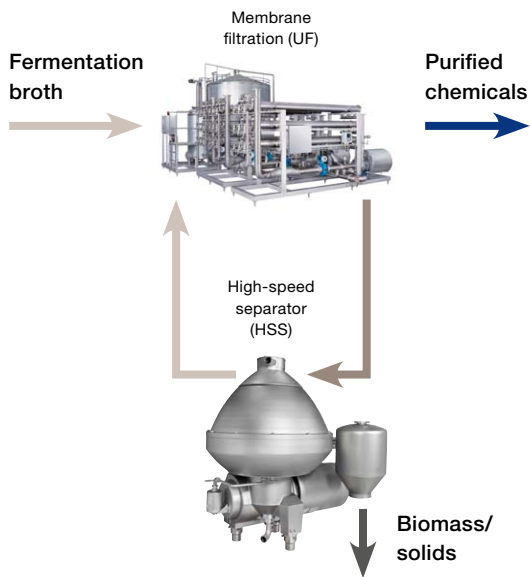
Having a broad view of the entire production process and how the different process steps interconnect lets you find new ways to improve operations.

It is first when you start looking at how the individual process steps affect each other that you can optimize the whole. Sometimes taking a step back inspires new, smarter ways to combine equipment, as shown in the example below.

Scaling up production, not cost

When a producer of organic acids was scaling up from demo plant to full-scale production, Alfa Laval's engineers designed a cell-removal system that improved yield and cut both installation and operating costs.

The obvious choice would be to scale up the process used in the demo setup where the broth was processed in two steps. First it passed through a high-speed separator where the cells were removed, and then it was purified in a second step using cross-flow membrane filtration. Just scaling up the existing design would have resulted in major investments and high operating costs.



Under the right conditions, the microbial cell removal and purification steps can be combined, resulting in higher yield and lower operating and investment costs.

Combining process steps to cut costs

Alfa Laval's engineers proposed a solution where the two steps are combined into one. Since the amount of cells in the broth is relatively low, it is possible to first run it through a membrane filtration stage where the product is recovered. The concentrate (cells and fluid) then passes through a high-speed separator where the cells are removed. The high-speed separator in this setup is specially designed for handling liquids with a high concentration of cells.

The clear fluid from the separator is led back to the membrane stage where the product is recovered. To avoid the build-up of accumulated fines that haven't been removed by the high-speed separation step, the membrane stage has a unique design and an automatic control system that regulates its operation.

The key benefits of this design are significantly lower investment costs and energy consumption as well as improved yield. The highly concentrated biomass resulting from centrifugation also minimizes the amount of water used for diafiltration and the need to remove additional water later in the process.

Results		
	Traditional process with separate steps	New process with combined steps
High-speed separators (HSS)		
Required number of HSS	10	2
HSS energy consumption	100%	20%
HSS service cost	100%	20%
HSS price	100%	22%
Ultrafiltration system (UF)		
Number of loops in the system	7	8
UF area	100%	110%
UF energy	100%	80%
UF service cost	100%	90%
UF CIP cost	100%	100%
UF price	100%	100%
Overall yield	≈ 97,5%	≈ 98,4%

2. Remove impurities at the right stage

Fermentable sugar is a major cost item in the budget for all manufacturers of bio-based chemicals. Cheaper sugar contains more impurities, such as fibres or proteins, than more expensive grades and requires plant owners to invest in equipment that removes them.

Since all processes are unique, one must analyse the feedstock and process to find the optimum setup for removing impurities. Some impurities are best removed before fermentation and some after, depending on the type of impurities, feedstock, product and process.

Some of the factors you need to take into consideration are investment costs, if the impurities are dissolved or suspended, separability, raw material and/or product loss. Often the optimum solution is to remove different types of impurities at different stages in your production process.

Investment costs

The most common way by far of removing suspended impurities from the sugar solution is to do it before the fermentation stage. But this requires investments in expensive equipment, and it is therefore generally cheaper to remove suspended impurities after fermentation.

Alfa Laval decanter centrifuges are perfect for separating out suspended impurities and can be used either before or after fermentation. Their high separation efficiency leads to high product yield and a very dry cake.

Decanter centrifuges are also often used in combination with high-speed separators and/or membrane filtration equipment to reach optimum results.

Product loss

The downside to removing impurities after the fermentation stage is that you lose a small percentage of the product. This means you have to take the price of the chemical you are producing into consideration. If the price is high, it is probably preferable to remove impurities before fermentation despite the higher investment costs (if the type of impurity, the product's physical properties and the purification process allow it). If you are producing a low-price chemical it is worth investigating whether



Alfa Laval decanter centrifuges are characterized by high separation efficiency, low power consumption, high capacity and easy handling.

the impurities can be removed after the fermentation stage instead. The efficiency of this type of solution depends on the properties of the produced chemical and the impurities.

By-products

If the impurities can be sold as a by-product, for example as feed for livestock, this will influence where you separate them out. The product is most likely not something you want in the by-product so you should therefore remove the impurities before the fermentation stage.

Separation efficiency

Suspended impurities, such as fibres, sometimes support the sedimentation process when separating out cells from the broth, and it may therefore be beneficial not to remove them before this stage.

Removing suspended impurities is easier when the viscosity of the mixture is low. It is therefore a good idea to compare the viscosities of the sugar solution and the broth before deciding where the impurities will be removed.

Removing dissolved impurities

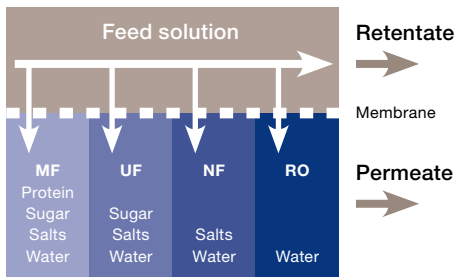
The fermentation broth will always contain dissolved impurities such as proteins, carbohydrates and colour bodies. They either come from the raw material or are by-products of the fermentation process.

These impurities are best removed at an early stage after fermentation. This will increase overall yield, lower operating costs and increase efficiency further downstream compared to removing them later in the process.

Removing dissolved impurities early reduces the load on, and fouling in, ion exchange resins and chromatography separation equipment, resulting in significantly lower operating cost and improved overall yield thanks to longer service cycles.

If a solvent extraction step is used, early removal of dissolved impurities typically means no wetting agent is required. For some products, higher purity will improve efficiency in crystallization processes and reduce the mother liquids volume.

The easiest way to remove dissolved impurities is to add a membrane filtration stage after fermentation.



Alfa Laval offers membrane filtration systems based on microfiltration, ultrafiltration, nanofiltration and reverse osmosis technologies.

Ultrafiltration is good for removing proteins, carbohydrates and colour bodies, and is sometimes combined with a centrifugation stage. Nanofiltration is typically used for simultaneous concentration and desalting. For some products, nanofiltration is used for final purification and for reducing concentrations of sugars, polypeptides, amino acids and salts.

Membrane processes usually operate continuously and with a sequential cleaning system set-up, depending on the flow rate and buffer tank system. Alfa Laval membrane filtration systems feature fully automatic control, feed flow, recovery and yield control with automatic optimization of operation pressure.

Cross-flow membrane filtration is widely used and has proven to be an effective way to achieve high yields and low energy costs in bio-based chemical production. Alfa Laval offers a comprehensive range of membrane filtration equipment based on microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) technologies.



Accurate temperature control of the fermentation process results in high production yield and a minimum of unwanted by-products.

3. Ensure accurate fermentor temperature control

Production yield is very dependent on accurate temperature control during the fermentation process. Keeping the microorganisms at a precise temperature is crucial for a high production rate and a minimum of unwanted by-products.

There are two ways of cooling the broth: either by running cooling water through an internal loop in the fermentation tank, or by running the broth through an external heat exchanger where it is cooled off.

High yield and minimum contamination

The best choice is an external, compact heat exchanger. Thanks to their small hold-up volumes they offer very accurate temperature control, thereby maximizing production yield.

A compact heat exchanger can work with a ΔT as low as 2°C (3.6°F). In many cases, this means you can cool the broth using normal water instead of chilled water and save on both energy and investment costs.

Using an external heat exchanger instead of an internal cooling loop also makes the tank easier to clean and minimizes the risk of contamination.

Alfa Laval heat exchangers are designed for compact performance and easy cleaning. Most often it is sufficient to use Cleaning-In-Place (CIP) equipment, which minimizes downtime and wear on gaskets and plates.

All our gasketed plate heat exchangers and spiral heat exchangers can be opened when necessary, giving maintenance personnel full access to all heat-transfer surfaces.



Alfa Laval WideGap heat exchangers are designed for handling fibrous media without clogging.

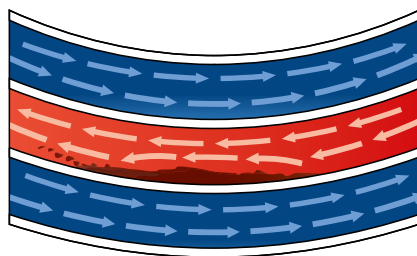
Fibrous media

When processing fibrous media it is important that the equipment does not clog up and cause costly downtime and cleaning.

Alfa Laval's WideGap plate heat exchangers are designed for media with high contents of fibres and coarse particles. The channels are much wider than in a normal plate heat exchanger, and depending on the configuration the plates have average gap widths of 5, 8, 11 or 17 mm (0.20, 0.31, 0.43 or 0.67 in). The specially designed, corrugated plates create a highly turbulent flow that helps reduce fouling and sedimentation. WideGaps are easy to service thanks to the design of the plates and frames. For example, the herring-bone pattern of the plates increases the cleaning effect during back flushing.



Our spiral heat exchangers excel at handling long fibres. The fluids flow through two concentric, spiralling channels in opposite directions. This design provides optimal flow conditions for a wide variety of fluids, ensures high heat transfer and keeps the overall size of the unit to a minimum. When fouling starts to build up, the pressure behind the deposit increases (thanks to the single-channel design) and when the pressure gets high enough the fouling is flushed out.



The single-channel design of an Alfa Laval spiral heat exchanger means fouling is flushed away as the pressure starts building up behind the deposits, resulting in a self-cleaning effect.

Each Alfa Laval heat exchanger is individually configured according to its specific operating conditions to optimize heat transfer, cleaning and operating costs.



4. Prepare for the future

Building a new plant or revamping an existing one is a big investment. It is essential to make the plant as future-proof as possible to maximize the return over time.

Tougher environmental legislation, ability to expand capacity, labour costs and changes in feedstock and energy prices are a few factors you need to take into consideration in the design phase.

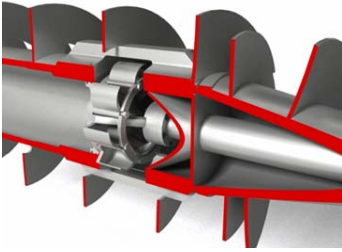
Energy costs

Energy costs are a major part of most chemical producers' budgets and energy prices are predicted to rise in the future. The difference in operating cost between two systems with differing energy consumption will therefore most likely increase with time. This makes choosing equipment and process designs with low energy consumption crucial to staying competitive.

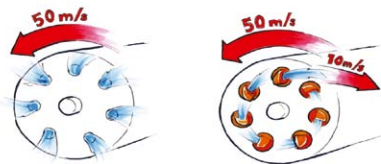
Evaporation systems

Evaporation systems are among the most energy intense parts of a processing plant. Adding evaporation stages – effects – is an easy way to cut energy costs. For example, going from two to three effects can reduce steam consumption by as much as 35%. AlfaVap heat exchangers are specially designed for evaporation duties and their compact size makes it easy to add effects to existing systems without major reconstruction. We help you design the entire system for minimum installation and operating cost.





The patent pending rotating feed zone reduces turbulence when the feed enters the decanter, resulting in improved separation, higher capacity and up to 40% lower power consumption.



The Power Plates liquid discharge can reduce power consumption by up to 40% by directing the flow of the exiting liquid so that its kinetic energy helps drive the bowl.

Decanter centrifuges

Alfa Laval decanter centrifuges feature a number of innovations that minimize electricity consumption. The patent-pending rotating feed zone available on some models reduces turbulence when the feed enters the decanter. This leads to improved separation, higher capacity and up to 40% lower power consumption.

The Power Plates liquids discharge directs the flow of the exiting liquid so that its kinetic energy helps drive the bowl. This reduces power consumption by 20-25% for 2-phase decanters and up to 40% for 3-phase decanters.

By combining a rotating feed zone with Power Plates, Alfa Laval's engineers have managed to cut power consumption by more than 50%.

Membrane filtration

The viscosity of a stream passing through a membrane filtration system changes as various substances are separated out. Taking the flux curve and the viscosity profile into consideration when designing our systems allows us to choose the optimum channel design for different parts of the system, as well as to optimize the number of stages. This results in up to 25% lower power consumption.

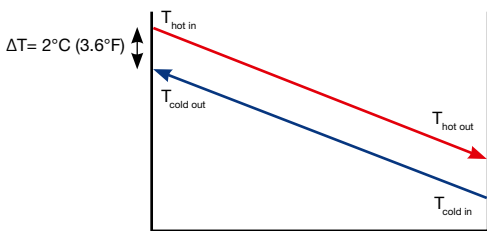
Heat recovery

Recovering waste energy from one part of your plant and putting it to use in another is a well-proven way to battle energy costs. Heat can for example be recovered from overhead condensers or hot process streams and, depending on the energy content and the needs in the plant, it can be used in a number of ways:

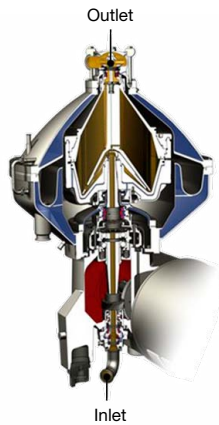
- Preheating of process streams, evaporation system influents or boiler feed water
- Electricity generation
- District heating
- Providing energy for chiller systems
- Heat tracing
- Producing distilled water

For maximum heat recovery, the heat exchangers must have a close temperature approach and operate with crossing temperatures. This means the cold stream is heated to a temperature very close to that of the incoming hot stream.

A highly turbulent, counter-current flow lets Alfa Laval heat exchangers heat a cold stream to a temperature just 2°C (3.6°F) below that of the incoming hot stream ($\Delta T = 2^\circ\text{C}$).



A close temperature approach and crossing temperatures maximizes heat recovery. An Alfa Laval heat exchanger can heat the cold stream to a temperature just 2°C (3.6°F) below that of the incoming hot stream.



Alfa Laval's hermetic high-speed separators have both the inlet and outlet at the centre of the separator. This reduces the power consumption by up to 25% compared to standard separators.

High-speed separators

Our unique, hermetic high-speed separators are the best choice for handling sheer-sensitive particles. They also offer up to 25% lower energy consumption than standard separators thanks to a special design with a hollow spindle inlet at the bottom of the bowl and a centrally located outlet at the top. Keeping both the inlet and the outlet at the centre of the separator minimizes the forces where the liquids enter and leave the separator, and thereby the power consumption.

Environmental legislation

As the general public and governments around the world become increasingly aware of the environmental problems our planet is facing, legislation and requirements are getting tougher.

You need to consider CO₂ emissions, water consumption, handling of GMOs and waste and wastewater treatment to name a few things.

Alfa Laval offers a range of solutions that help chemicals producers minimize their environmental impact, for example by recovering energy, preventing the release of GMOs to the surroundings, reducing waste and lowering the amount of chemicals discharged to the environment.

Expanding capacity

It is very likely that at some point you will face a need to increase plant capacity. This makes flexibility an important factor when choosing equipment. How easy will a future revamp be with the equipment you are investing in?

Make sure that you choose equipment from the start that is easy to expand and offers high performance per installed area.

Good examples of this are Alfa Laval evaporation systems and gasketed heat exchangers. Increasing capacity is easily done by just adding more heat exchanger plates to the existing frames.

Another example is our membrane filtration equipment, which features a modular design. This gives you a high degree of flexibility and makes your system easy to expand when production increases.



5. Cut costs with counter-current diafiltration

Continuous diafiltration is a common way of removing impurities such as salts, solvents and small molecules from the product solution. The process traditionally requires large amounts of water to wash out the unwanted substances. The added water increases the total production costs, both in the diafiltration stage and further downstream when the water has to be removed again.

Reusing wash water

Alfa Laval has developed a new design for continuous diafiltration that dramatically reduces water usage. Instead of adding fresh water in each diafiltration step, the permeate water is reused in previous steps. Fresh water is only added in the last step, and the permeate from the last step is reused as wash water in the second-to-last step, etc.

This unique design leads to large savings in water consumption. With Alfa Laval's continuous, counter-current diafiltration system you can save up to two thirds of the water consumed in a conventional system.

Major savings

Adding water in a diafiltration stage dilutes the product. This water has to be removed further downstream, for example through evaporation or reverse osmosis, adding to the investment and operating costs.

The big reduction in the amount of added water means Alfa Laval's counter-current diafiltration systems minimize costs in both the purification and concentration stages of your plant.

6. Balance operating and investment costs

To successfully set up and run a full-scale production plant you need to take a lifecycle view of the total costs and earnings. To maximize plant profitability over time you must find the optimum balance between investment costs, operating costs and income.

The initial investment is often less than the total cost for operating and maintaining the plant over its entire lifetime. This means investments in equipment that reduce operating costs and increase production yield are generally good for business in the long run, even if the initial cost is higher.

Scaling up

When scaling up from pilot or demo size to full-scale production, the balance between investment and operating costs often shifts dramatically.

Operating costs are rarely an issue in a pilot plant where the main focus is to show that the process works. When building a full-scale plant, you must pay close attention to operating costs and carefully consider all possible savings.

A good example of this is evaporation systems. In a demo plant, you are probably not minimizing energy consumption as much as possible. The extra investment in equipment this would require is not worth it.

However, when building a full-scale plant that will be operational for many decades, you can save an enormous amount of energy by investing in heat recovery, extra effects or a mechanical compressor. The payback time for the extra investment may be as short as two years, depending on the size of the plant.

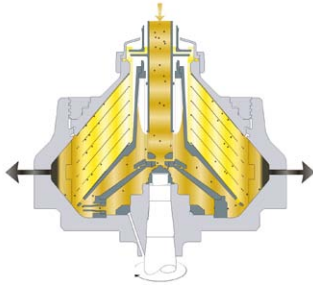
Scaling up also opens up possibilities for designing process stages in a new way. One example is the case described in section 1 of this whitepaper where two steps in a demo plant could be combined into one in the full-scale plant.

At Alfa Laval, we help you find the best combination of equipment for your specific plant and make sure your yield is high and your total life-cycle costs low.

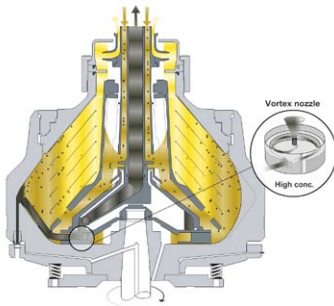


Two-stage evaporation system in a demo plant.

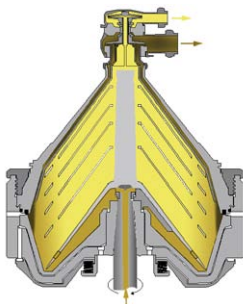
Each separator model is optimized for use under certain operating conditions. We help you analyse your process and find the right models for each stage.



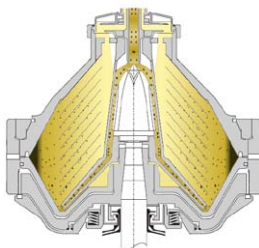
Type SX is good at handling fluids with high cell content and solid impurities.



Type UX can handle both high and low cell contents.



Type Bactofuge is suitable for use with small-size microorganisms and when cell content is high.



Type PX is designed for low cell content and handles solid impurities.

7. Choose the right high-speed separators

High-speed separators are critical components in several steps in bio-based chemical production, for example microbial cell removal.

The efficiency of your high-speed separators affects your yield a great deal, and it is essential that they deliver peak performance.

Therefore you must choose high-speed separators that are matched to your specific operating conditions. Factors such as the concentration of cells and impurities in the fermentation broth, if the fermentation is performed by yeast cells or bacteria, viscosity, density and the properties of the chemical you are producing must be analysed when choosing high-speed separators.

Alfa Laval offers a wide range of high-speed separators, including hermetically sealed models. This means we can always help you find the perfect equipment for your process.

Yeast requires a much smaller clarification area

One factor that affects separation a great deal is the size of the cells performing the fermentation. Yeast cells are roughly 6-8 times larger than bacteria and are therefore much easier to separate out from the fermentation broth.

During the research phase, it is sometimes possible to choose whether you are going to develop a process based on yeast or bacteria. If you have this opportunity, you should choose yeast rather than bacteria to cut separation costs.

With yeast you need less separation equipment, which will save both investment and operating costs. For example, if you need to process 100 m³ fermentation broth per hour, you need one high-speed separator if you are running a yeast-based process. If you are using bacteria, you will instead need 6-10 high-speed separators (with a similar clarification area).

Since high-speed separators rotate at high speeds both power consumption and service costs need to be considered. So if you can get the job done using one separator instead of ten you will make large cost savings over the lifetime of the equipment.



A multi-effect evaporation system

8. Design your evaporation system for maximum benefit

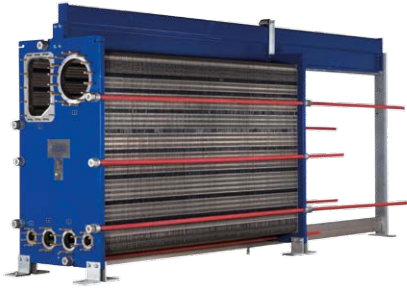
Evaporation is used in many bio-based chemical plants and is often the position which consumes the most energy. Choosing the right evaporation system not only minimizes energy consumption, but also reduces investment costs and improves product quality.

Minimize energy consumption

Energy costs is a major part of most chemical producers' budgets. As energy prices are predicted to rise over time, it is crucial you make sure your plant is as energy efficient as possible to stay competitive.

There are several different ways to reduce energy consumption in an evaporation system, for example by using multiple effect evaporation, thermal or mechanical compressors and preheating with waste heat from the evaporator itself or other process steps.

When designing an evaporation system, you need to balance the costs and savings that come with different options. Adding more effects saves operating costs but means you need to invest in more equipment. Mechanical compression of the vapour comes at a lower operating cost than thermal compression but the investment cost is higher.



AlfaVap is a range of semi-welded heat exchangers designed for evaporation duties. AlfaVaps feature high thermal efficiency, compact size and are designed for full vacuum operation.

We are glad to help you design the optimal evaporation system for your plant. We analyse a number of factors such as production rate, product price and steam cost to work out the perfect balance between investment and operating costs from a lifecycle perspective.

Reduce investment costs

Where other solutions need several floors, lots of piping and large recirculation pumps, the low height of the AlfaVap system makes it possible to install in one floor with small pumps (or even without). This results in significantly lower installation, building and equipment costs.

Improved product quality

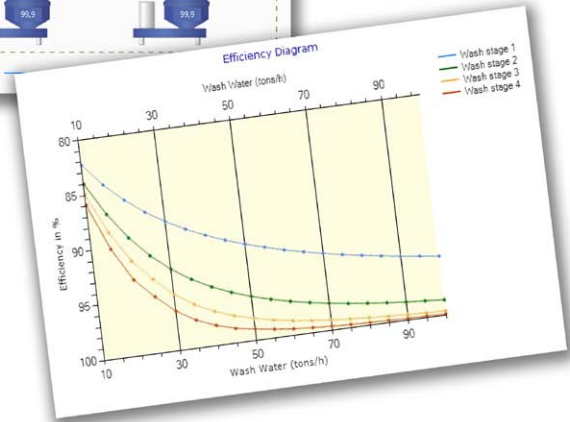
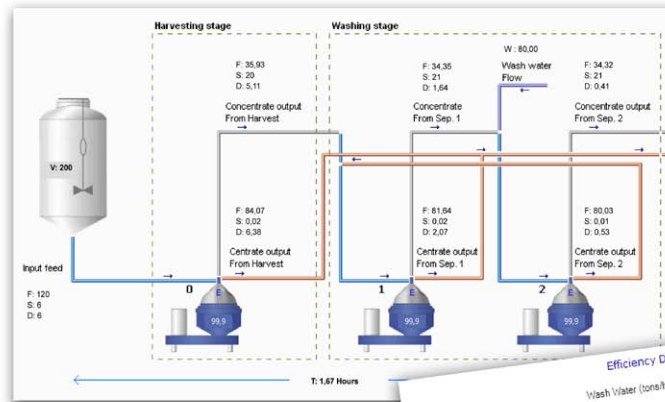
The low hold-up volume in the AlfaVap system means the product has a short residence time in the evaporation system. This minimizes product degradation due to high temperature and secures high quality for the end product.

The low hold-up volume also ensures fast and smooth start-up and easy process control.

Recycle the condensate

Running the condensate through a membrane filtration system makes it possible to reuse it as process water, thereby cutting both costs and environmental impact.

Using our specially developed software, we can help you calculate the benefits of cell washing.



9. Check if washing will increase your profits

The cells that have been separated out from the broth in the microbial cell removal step hold fluid with the same product concentration as the cell-free broth.

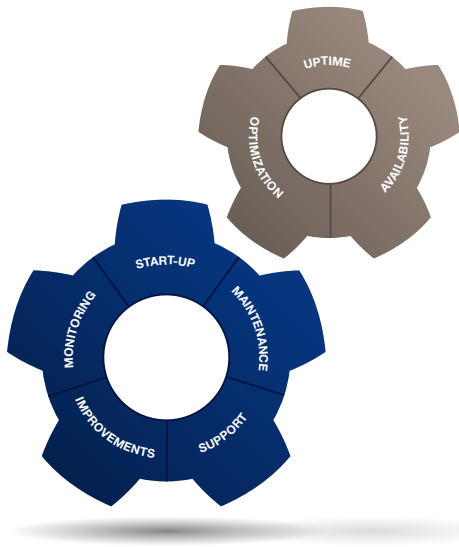
Washing these cells lets you recover the product from extracellular and intracellular liquids. The cells are thereafter removed from the washing water in a high-speed separator and the diluted product is returned to the main production stream.

The washing process can be repeated in several stages to recover as much product as economically viable. Washing can increase the yield by a few percent, which can have a significant effect on your bottom line.

Washing not only increases the yield but also investment and operating costs. This means you have to do a detailed analysis to find out how much the yield will increase and if the added costs are justified by the extra amount of product produced.

We have developed special software that allows us to analyse if washing is profitable and, if so, the optimum number of washing steps. We will be happy to calculate the possible benefits of adding a washing system in your plant.

10. Optimize service and maintenance



Alfa Laval's 360° Service Portfolio includes all the services you need to ensure high performance, uptime and operating efficiency throughout the entire lifecycle of your Alfa Laval equipment.

Regular maintenance is key to achieving optimal operating efficiency and return on investment. With well-planned service, you get:

- Low operating costs
- High performance
- Maximum uptime
- Long maintenance intervals

Service when needed

Condition monitoring is a great help for efficient service planning. A condition monitoring system measures the exact condition of the equipment and lets you know when service is needed. This means you optimize service intervals according to the actual need of the equipment. This ensures high performance, minimizes the risk of breakdowns and reduces service costs.

Performance Agreements

Another way for plant owners to optimize service while minimizing costs is to enter into a Performance Agreement with Alfa Laval. This is a tailor-made service solution that can include any of the services in Alfa Laval's 360° Service Portfolio. With a Performance Agreement, you have full control over your service budget and total piece of mind.

Global service network, local support

Going from the pilot and demo stage to commercial production often involves a geographical move as well. This makes it important to choose a supplier that has the ability to assist you in different parts of the world as your business develops.

With Alfa Laval as your service partner, you get full support on a global scale. Over the past 130 years, Alfa Laval has built a global service network with a strong local focus. Alfa Laval has service specialists ready to assist you in nearly 100 countries and our efficient logistics chain makes sure you get any spare parts you may need on time.



Contact Alfa Laval

This whitepaper has covered just a few of the tips we have to offer. We would be glad to meet with you to discuss opportunities in your bio-based chemical plant.

You can find contact information for your nearest Alfa Laval representative on our web site: www.alfalaval.com.

We look forward to hearing from you.

Alfa Laval in brief

Alfa Laval is a leading global provider of specialized products and engineering solutions.

Our equipment, systems and services are dedicated to helping customers to optimize the performance of their processes. Time and time again.

We help our customers to heat, cool, separate and transport products such as oil, water, chemicals, beverages, foodstuffs, starch and pharmaceuticals.

Our worldwide organization works closely with customers in almost 100 countries to help them stay ahead.

How to contact Alfa Laval

Contact details for all countries are continually updated on our web site. Please visit www.alfalaval.com to access the information.



www.alfalaval.com/bio-based-chemicals