Dairy Optimization 101

By Robbie Turner, Dir. of Optimization Solutions - Europe • an Austin Data Labs whitepaper

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Introduction

In this white paper, we examine the concept of optimization in the dairy supply chain. It will give you a detailed understanding of the key themes and concepts within the realm of dairy optimization – specifically within dairy commodity processing. That said, the themes, concepts, and wider economics detailed below are applicable to all disassembly production lines – most notably agricultural commodities.

What is Dairy Optimization?

Colloquially, optimization is often said to be "doing the best with what you've got." It is the rules, processes, and frameworks through which you evaluate your options in order to maximize a particular objective function. Many companies struggle to truly "do the best with what they have." When companies adopt a scarcity mindset, it's easy to miss the advanced tools and knowledge that would help optimize these complex organizations and supply chains.

From a theoretical standpoint there is only one requirement for optimization: the presence of multiple decisions tied to multiple differing outcomes[1]. Without informed choice there is no agency, and therefore no possibility for optimization. When you optimize, you're seeking to process all available information in a way that allows you to rank the alternative outcomes, then make the best choice.

As this paper expands on optimization as it relates to dairy commodity processing, it will cover the following topics:

1. What is milk – how does it change with time
2. The dairy commodities market – how does it impact your decision making
3. The economics of disassembly versus the economics of assembly
4. Tactical optimization – how do you get the best results today
5. Dynamic optimization – how do you get the best results in the future
6. Real options – what is the value of flexibility and why companies rarely fully commit.

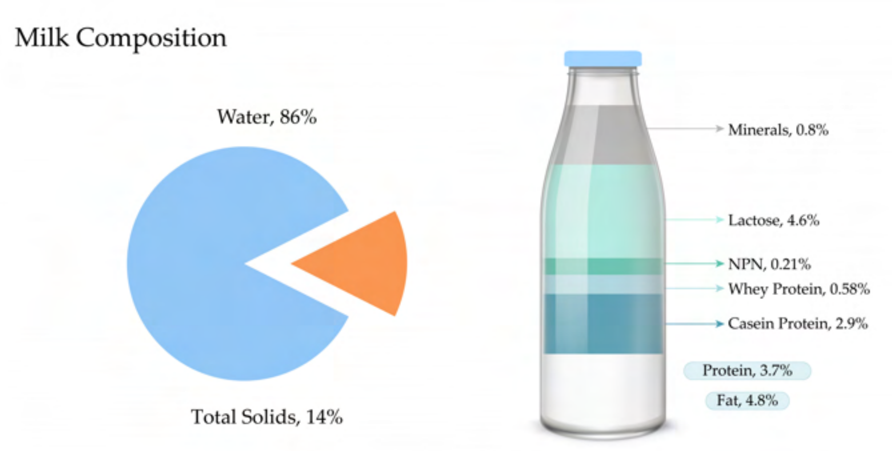
Additionally, the following themes will provide the structure and lens through which this paper analyzes these topics. Namely:

1. Scarcity – how limited resources impact your range of outcomes[2]
2. Direct influence – how your actions immediately impact your range of outcomes[3]
3. Indirect influence – how your actions impact your future range of outcomes[4]

But first…

What is Milk?

When I talk about milk from an optimization standpoint, I am talking about its components. The components of milk are the building blocks for your end products, such as butter and cheese. Understanding how much of each component is present and its relativity to other components is crucial to the optimization process.



Generally speaking, milk is 86% water and 14% solids. That 14% is what you typically care about and is composed of fat, casein protein, whey protein, lactose, minerals, and non-protein-nitrogen. Throughout the year the absolute value of these components and their relativity to each other will change. This change is most pronounced in pasture-based farming environments, such as New Zealand and Ireland, where the composition of the grass changes dramatically throughout the year. For example, in the New Zealand spring flush, when milk volumes are at their peak, the actual solids content in the milk is lower – therefore the milk has a higher water content[5].

This variation in solids has massive implications for production scheduling. Making sure you have the right building blocks at the right factories on the right day is a must. This means understanding the compositional make-up of milk and how that varies on a day-to-day basis is crucial if you are to optimize your production and use your available production capacity in the most efficient manner.

When processing milk, you typically start by separating the milk into two streams – a fat or cream stream and a skim milk or protein stream. Starting with your cream stream, you can choose to sell it as-is or further process it into butter and anhydrous milk fat (AMF)[6]. Your protein stream can either be dried and packaged as skim milk powder, or further processed into the individual protein streams – casein and whey[7]. Alternatively, you can add cream back into your protein stream to create whole milk powder (WMP) or cheese. You can even further refine, mix, and match our fats and proteins to create a raft of niche and high-value products.

What is Milk? con't

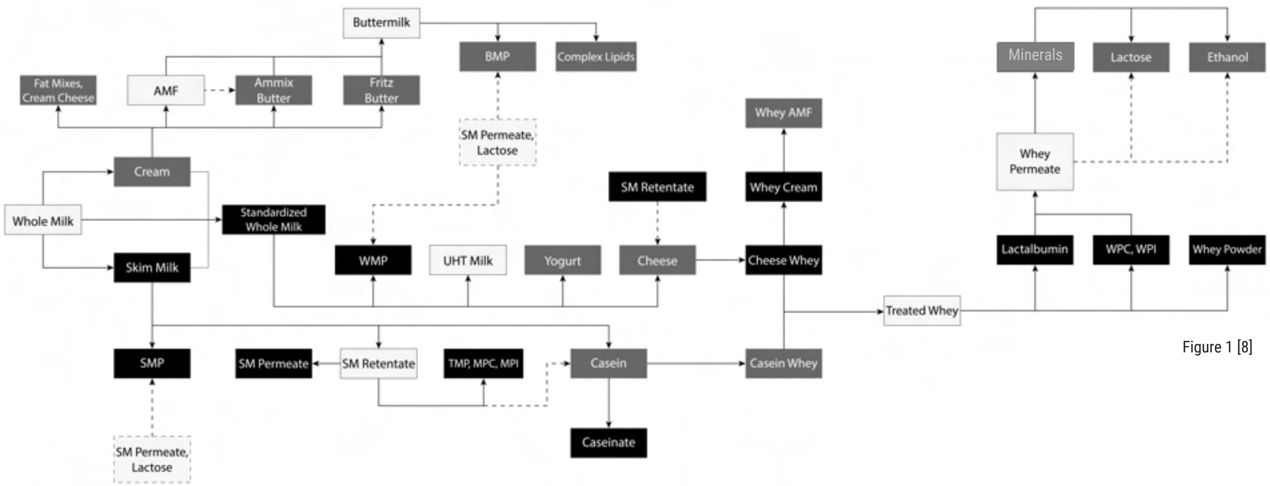


Figure 1 [8]

In effect, the companies in the dairy supply chain view milk as a series of building blocks from which to build a range of different dairy products. The number of these building blocks that you find within your milk supply varies depending on a cow's feed, breeding genetics, weather, and point in the lactation cycle. Thus, it is crucial that you consider how your bills of materials vary with time when optimizing.

The Dairy Market

When choosing how you assemble your milk building blocks, you're bound by two key constraints. First, what can your factories actually make – after all, you can't get WMP out of a butter churn. Second, what does the market want you to make, as communicated via demand and price.

Dairy plant capabilities are typically fixed in the short-term, so the question then becomes: given what you're able to make (your production constraints), what should you make? In order to answer this question, you need to consider your product streams as a whole. When dairy plants process dairy, they don't just make one product. The plants make a series of products in differing volumes in order to extract all the value from the initial 'bucket' of milk – there is no sense in choosing to make butter and then throwing the protein away. That means you can't just compare the returns from producing the individual commodities, but rather must evaluate the returns from the full stream of commodities and their corresponding volumes.

In short, if you choose to make SMP, you must also factor in how much butter you'll have to make, what it will cost to make, and how much you'll get for it. Failure to do so is a failure to balance your input (bucket of milk) with your outputs, which leaves value on the table.

The Dairy Market, con't

For example, consider the following tables:

1. **Table 1** shows the market prices and production costs for dairy commodities per MT
2. **Table 2** shows the production yields (volumes in MT) of each commodity per MT of input milk solids – think of this as your bucket of milk

Table 1. Market Prices

Product	Price $/MT	Cost $/MT
WMP	3,200	600
SMP	3,100	300
Butter	4,000	1,500
AMF	5,000	1,800

Table 2. Streams & Production Yields [9]

Stream	Base MT	Butter MT	AMF MT
WMP (Butter)	1.75	0.25	
WMP (AMF)	1.75		0.2
SMP (Butter)	1.25	0.5	
SMP(AMF)	1.25		0.4

The question is, to what stream should you allocate your milk?

Examining the WMP (butter) stream you can simply sum up the margin times yield for each product to find the total return. That is:

$$WMP\ (butter) = \big(WMP\ yield * (price - cost)\big) + \big(butter\ yield * (price - cost)\big)$$

$$= \big(1.75 * (3{,}200 - 600)\big) + \big(0.25 * (4{,}000 - 1{,}500)\big)$$

$$= \big(1.75 * (2{,}600)\big) + \big(0.25 * (2{,}500)\big)$$

$$= 4{,}550 + 625$$

$$WMP\ (butter) = \$5{,}175\ per\ 1MT\ of\ milk\ solids$$

The Dairy Market, con't

Repeating the exercise for the remaining product streams gives:

$$WMP\ (AMF) = \$5{,}190\ per\ 1MT\ of\ milk\ solids$$

$$SMP\ (butter) = \$4{,}750\ per\ 1MT\ of\ milk\ solids$$

$$SMP\ (AMF) = \$4{,}780\ per\ 1MT\ of\ milk\ solids$$

In this example the best returning product stream is WMP as the base-product with AMF as the by-product. As market conditions change, the ranking of product streams changes and there have been numerous cases of the tail wagging the dog. That is, cases in which the dramatic price swings in the “by-products” drive changes in the product streams. Consider my example above. WMP returns, regardless of what you do with the remaining cream, are above those from SMP. But when dairy plants make SMP they have significantly more cream than when the plants make WMP. At what point does the price of butter change your behavior?

$$SMP\ (butter)\ \geq WMP\ (butter)$$

$$\big(SMP\ yield * (price - cost)\big) + \big(butter\ yield * (price - cost)\big) \\ \geq\ \big(WMP\ yield * (price - cost)\big) + \big(butter\ yield * (Price - Cost)\big)$$

$$\big(1.25 * (3{,}100 - 300)\big) + \big(0.5 * (butter\ price - 1{,}500)\big) \\ \geq \big(1.75 * (3{,}200 - 600)\big) + \big(0.25 * (butter\ price - 1{,}500)\big)$$

$$3{,}500 + 0.5 * butter\ price - 750 \geq 4{,}550 + 0.25 * butter\ price - 375$$

$$2{,}750 + 0.5 * butter\ price\ \geq 4{,}175 + 0.25 *\ butter\ price$$

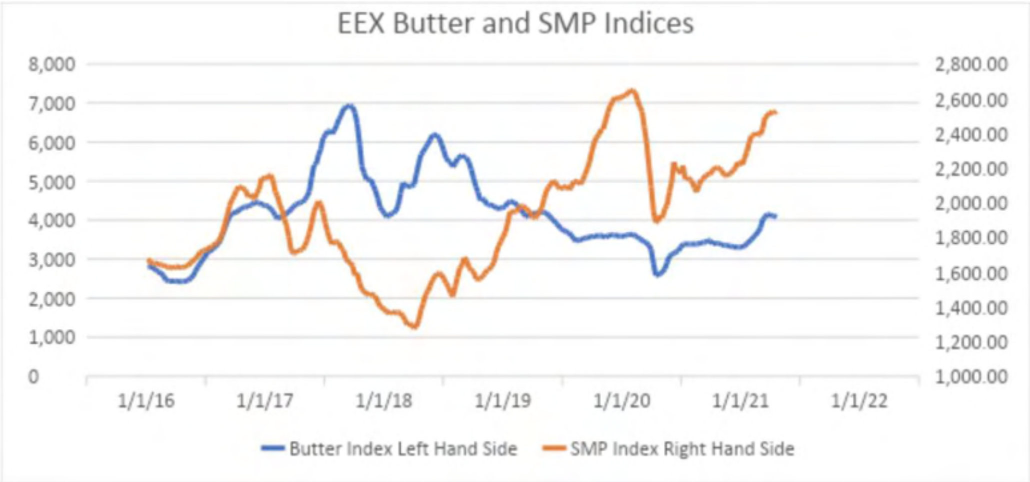
$$0.25\ butter\ price\ \geq 1{,}425$$

$$Butter\ price\ \geq \$5{,}700/\mathrm{MT}$$

In this example, if the price of butter was to rise above $5,700/MT while all remaining pricing and costing remained constant, you would then reallocate the milk assigned to WMP product to SMP production.

The Dairy Market, con't

In reality, pricing rarely remains constant, and the merit order of product streams typically changes across the season. Generally speaking, dairy processors find that in the short-term dairy commodity pricing is driven by demand for the individual products, while in the medium to long-term it is driven by the returns to product streams in their entirety, as milk is allocated to streams, not individual products.



A real-life example of this is the great European butter rally of 2017 where pricing spiked to almost EUR 7,000/MT. The result of this insatiable demand being a monumental increase in SMP production; an increase that correspondingly crashed the market[10].

Disassembly Economics

The economics of disassembly are not simply the inverse of the economics of assembly.

With assembly you would optimize incrementally. At each new step you'd add the most cost-effective component required to meet a minimum output specification. What this means is that at each step in the production process you can reassess your plan and re-optimize. In effect there is no “memory” and you're not bound by the decisions of the past (to a certain extent).

The converse of this is true for disassembly. When you optimize during the disassembly process, you're making decisions that will dictate your available choices in the future. By committing to one course of action, one particular product stream, you limit yourself as to what you can do next.

The consequence of this is that you need to be more certain in your initial decision making, and must be confident with your tools and processes.

Disassembly Economics, con't

Understanding variable costs and fixed costs and, most importantly, marginal cost[11], is also necessary. When valuing each stream, dairy producers often work only with marginal cost.

Why? Plant, labor, and overheads are fixed in the short term, regardless of what products are made. Also, milk has to be processed; since dairy plants are often obligated to take it, as it is perishable (not to mention overheads per unit skyrocket if you don't run the plant), diary plants often only focus on the incremental processing costs since all other costs will be incurred otherwise.

And finally, when valuing the returns from a particular stream it's important to consider the opportunity cost. Coming back to the fact that milk is perishable and dairy plants must use it, you should only evaluate the incremental profit achieved (i.e the total revenue minus the opportunity cost). This is crucial, as one stream may return slightly above the others, but if the product failure rate is higher and consequently there is greater potential for downgraded product, marginal gains can easily be erased.

Tactical Optimization

Tactical optimization is the name for in-season, short-term optimization, like the examples above.

Tactical optimization takes constraints as given: fixed and unchangeable. It also typically sees the optimizer responding to immediate (or near-term forecasted) changes in market dynamics, such as a change in the relative pricing between cheese and butter. Tactical optimization is concerned with getting every last cent out of a bucket of milk given the production, costing, and demand realities facing dairy processors in a given moment.

Additionally, tactical optimization is concerned with finding and exploiting arbitrage opportunities that arise due to imperfect information, market geometry, market geography, and external price shocks. Tactical optimization typically deals with the redistribution of resources – in our case milk solids – given new information.

In order to be successful at tactical optimization, a dairy producer must have flexibility within its production footprint. For example, if you have a drier that can only make SMP and only a butter churn for the cream stream then the only tactical optimization you can do is to decide if you sell the raw milk or split it into cream and protein and then if you churn or sell the cream and if you dry or sell the SMC[12].

Dynamic Optimization

Dynamic optimization is the name for cross-season, long-term optimization.

Dynamic optimization typically sees the optimization of a portfolio, rather than a product stream, over time. It sees the buying and selling of production assets as well as the construction of both brown and greenfield sites. It is typically concerned with innovation and trends – both new and forecasted. It seeks to meet the shifts in consumers' consumption behavior and tries to anticipate what that behavior will be in the future. Dynamic optimization is less concerned with exploiting arbitrages in the here and now, rather seeking to create and exploit future arbitrages.

When dynamically optimizing over a long enough timeline all constraints move from fixed to variable. This means the constraints that limited our behavior are no longer factors. However, this comes at a price and that is that in the long-run, all fixed costs become variable and will need to be considered.

Raw milk itself is less clear cut. In some instances, dairy co-ops are obligated to always collect their members' milk, in which case milk would be considered a fixed cost and thus outside the scope of dynamic optimization[13]. If, on the other hand, additional milk must be bought in order to run the plant, then this cost must be included in the optimization equation. Understanding how a firm procures milk (their input) is key to understanding how they will invest their capital[14].

The Value of Real Options

When you commit to supply a customer a certain product, you impose additional constraints on your dairy operation, reducing your ability to profit should market conditions change. In the immediate and short-term these constraints are often trivial; for the most part, you typically look to confirm orders of the highest returning product streams.

However, as you confirm orders into the medium and long-term, you begin to impose real and binding constraints that will affect how you can respond to changing market dynamics. For example, if you have a dryer that can produce both WMP and SMP and then enter into a contract where you commit half of that dryer's capacity to meet a customer order for WMP in the future, you have in effect reduced your flexibility by half. Should the relative value of WMP and SMP change and the SMP product stream become more desirable, you have effectively reduced your ability to profit from this by half.

The Value of Real Options, con't

Consequently, you need to strike the right balance between contracting long-dated orders as a means of risk management and retaining the optionality of our assets.

In my next paper I will explore this concept of real options in greater detail – including how to price this production flexibility. Additionally, I will explore the concept of risk management, and how it interacts with real options.

Summary

While the economics of disassembly optimization may appear complex, the intuition is simple: you are trying to do the best with what you have.

By understanding your plants, your inputs, and the markets you operate in, and by utilizing the expertise of Austin Data Labs, you can take your business to the next level through our industry expertise and thought-leading B2B SaaS.

About the author: Robbie brings expertise in production and asset optimization in the dairy industry to Austin Data Labs. Having spent the past 15 years in commodity markets, he is well versed in commodity market supply chains – from raw material origination and harvesting through processing optimization and price risk. Robbie has held prior roles in optimization and portfolio management at Fonterra, and has brokered dairy trades for some of the biggest dairy firms while heading up Rice Dairy's EU office. Robbie has a Master Degree in Microeconomics and Game Theory from the University of Auckland, and served as a course auditor for the Foundations of Commodities paper at the JP Morgan Business School at the University of Colorado, Denver.

Work With Us

We'd love to help you solve your stickiest challenges. Drop us a line or give us a call. We can't wait to roll up our sleeves and get our hands dirty optimizing your dairy supply chain.

e: robbie.turner@austin-labs.com
o: +1 (512) 957-0896

End Notes

1. Strictly speaking, these outcomes must be measurable – that is, we can assign a ranking or preference to them. And these preferences must obey transitivity. Transitivity being the notion that if A > B, and B > C, then it follows that A > C.
2. When resources are unlimited then there is no requirement to allocate them to their best use, as there is enough resource to be allocated to all possible uses.
3. Think elasticity and how our decision to produce more of good A impacts on the dynamics (price) of good A.
4. Referring to cross-product elasticity and how our decision to produce more of good A impacts on the dynamics (price) of good B, and additionally how this decision to produce more of good A today may impact the market for good A in the future.
5. It is worth noting that milk composition varies greatly between regions and countries and is attributed in most part to a cow's diet. In New Zealand and other pasture-based systems the milk is typically high in protein and requires the addition of lactose during the production process to meet the CODEX specifications for milk powders. Inversely, the US dairy farming system is predominantly feed-based (higher in fats and sugars), resulting in an excess of lactose that is often exported to New Zealand. This is also due to the product mix in the USA which favors cheese production over powders.
6. Given fresh cream's perishability and relatively low demand, the vast majority of it is processed into butter and AMF. Butter is typically 82% fat, 18% moisture and AMF is typically a further refining to increase the fat content to 99.99%.
7. These products can then further be refined into caseinates, milk protein concentrates, whey protein isolates etc.
8. Note, permeate is the term for the combined lactose, vitamins, and minerals that result from filtering milk (whole or skim) through a fine membrane, known as ultrafiltration. In case where the percentage of protein in the milk is too high, permeate can be added to the milk to dilute this – in the same principle as lactose standardization. Retentate is what's left over after the permeate has been removed. Given non protein solids have been removed through the Ultrafiltration process (that is, the permeate has been removed), the protein concentrate in retentate is higher than milk and therefore it is commonly used in Milk Protein Concentrate (MPC) products.
9. Note: these production yields are illustrative only.
10. Arguably, this decrease in the price of SMP drove the butter market higher, as the threshold required to make the product stream attractive to producers kept rising proportionate to the fall in SMP pricing. Additionally, this chart shows some interesting interactions between the two products. SMP (Butter) is a common product stream, and we can see the times in which both products are rising or falling corresponds to a wider rise or fall in dairy commodity pricing, and the times in which the product are inversely related corresponds to times when demand is focused on a specific product, and not dairy as a whole. During these times the other components in the stream adjust to balance their own supply and demand.
11. We produce until marginal cost equals marginal revenue. Why? Because if marginal revenue is above marginal cost then we are continuing to make a profit. If marginal revenue is below marginal cost, then we are making a loss, thus in order to extract all the value out of our input, we continue producing a certain good until there is no incremental benefit from doing so.
12. There are also options around what specification of SMP you can make, but this is consider tinkering around the edges.
13. However, milk is very much key to dynamic optimization when it comes to forecasted future volumes. The majority of production capacity commissioned in the more commoditized products – think general SMP, WMP, Butter – is built in response to growing milk pools.
14. For example, a Co-Op that is obligated to collect its members' milk will need to build assets in response to growth (real and forecasted) in its members' milk supply. A firm that only buys what it needs when it needs it will typically only invest when there is a strong economic incentive to do so, and will rarely invest heavily in standard commodity products.