PATHFINDING TOWARDS PRECISION FERMENTATION VIABILITY

gfi / Europe

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Executive summary

Overview

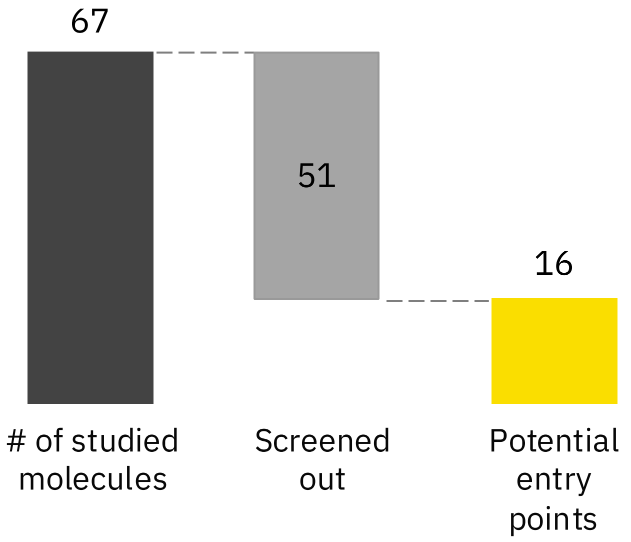
Precision fermentation (PF) has enabled the production of key food ingredients for decades, and its potential is now expanding to the alternative protein industry – but commercialising these innovations remains challenging due to cost barriers, especially for commodity molecules. To address this, **the Good Food Institute Europe and Arthur D. Little Consultancy partnered to develop a structured framework to help companies identify commercially viable target molecules** that can support companies in the near-term to reduce risk, build capabilities, and lay the groundwork for scaling towards broader impact. This can help companies bridge the 'valley of death' and ultimately deliver on PF's full potential to reduce environmental impacts and boost food security.

Key findings

- Of the 67 precision fermentation molecules analysed, ~24% have promising market potential based on lower unit cost estimates compared to current market prices for conventionally-produced molecules.
- The most viable opportunities exist for proteins (instead of fats and lipids and other small molecules) with high functional value and premium applications.
- Further optimisation of key variables, such as target yield on substrate, substrate costs, culture volume at harvest, and titre at harvest could significantly reduce unit economics. As the sector advances its technology and processes, more molecules could become viable candidates for competitive production through precision fermentation.

67 Number of molecules considered in this study

24% Share of molecules with potentially viable entry opportunities based on conventional market prices and the estimated cost of production via precision fermentation



Recommendations

Corporates that act today can secure upstream control and differentiation; startups that stay laser-focused on unit economics and partnerships will survive the "valley of death" and maximise value

Corporations

1. **Set up a PF "Opportunity Radar":** Formal scouting to identify molecules that have viable market entry points, large market opportunities, and low saturation.
2. **Secure platform footholds:** Pursue joint ventures or contract manufacturing deals that convert idle fermentation assets into PF-ready capacity.
3. **Build PF-made ingredients into the foundation of future product innovation:** Incorporate PF ingredients into new product development where it can support ESG goals and enable differentiated product growth.
4. **Adopt a flexible, stage-gated approach to PF:** Fund projects incrementally, end low-potential efforts early, and scale up winners decisively.

Startups

1. **Rigorous product-market fit check:** Use structured frameworks to focus R&D on molecules with viable entry points and clear differentiation.
2. **Exploit "cost-in-use" storytelling:** Shift from $/kg to $/functional-dose to highlight PF's competitiveness even if headline cost of production (CoP) lags conventional benchmarks.
3. **Leverage corporate muscle:** Pursue "anchor off-taker" or "shared capex" models with food and beverage majors to plug the scale-up funding gap and fast-track regulatory approval.
4. **Expand platform potential:** Once a strain/downstream processing (DSP) combination is proven, rapidly branch into adjacent molecules with shared technical attributes to expand addressable markets with minimal incremental capex.

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Introduction

Precision fermentation has long played a role in food production. It is used today to produce essential ingredients for the food industry, including rennet for cheesemaking and citric acid for food preservation. Today, innovators are expanding the potential of precision fermentation as a technology to produce functional proteins, such as egg and dairy proteins, specialty ingredients like heme and oils and fats like palm oil.

Many companies face hurdles in bringing ingredients for commodity applications to market at cost-competitive levels. While significant advances have been made in strain engineering, feedstock optimisation, and bioprocess design over the past few years, many efforts are targeting commodity molecules – high-volume, low-margin products that are difficult to commercialise without large-scale cost reductions.

The Good Food Institute Europe (GFI Europe) and Arthur D. Little Consultancy partnered on a project to develop a framework for identifying viable molecules for precision fermentation market entry. By building a foundation on near-term feasible target molecules, companies can reduce risk, build capabilities, and lay the groundwork for scaling toward broader impact. This report details a structured approach to guide target molecule selection, and examples of case studies that demonstrate how to analyse high potential molecules for commercial and technical feasibility.

Introduction

An important caveat of this research is that premium markets are normally an intermediate solution. Targeting high-value, niche applications can play an important role during the early commercialisation phase. However, premium markets are typically not a long-term growth strategy.

In most cases, niche opportunities are part of a broader strategy to eventually reach large, cost-sensitive markets, where cost reduction is essential. If products remain expensive, they will be confined to small premium segments, which often represent only hundreds of metric tonnes (MT) annually. These markets are structurally limited in size and cannot absorb the output of large-scale production facilities. Efforts to expand niche markets usually face diminishing returns: as supply increases, prices tend to fall, undermining the business case for scaling. Premium segments also come with structural hurdles. Customers in these markets often have long sales cycles, slow adoption rates, and gradual market expansion. These dynamics make it difficult to achieve the rapid growth required to support significant capital investments.

Despite their limitations, identifying and targeting early premium niches remains critical. These markets can provide essential early revenues, proof points for investors and partners, and valuable learning opportunities. When integrated into a broader scale-up strategy, they serve as a crucial bridge – helping companies de-risk their technology, refine their value proposition, and build the capabilities needed to access larger, mainstream markets.

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Project scope and approach

Bringing a precision fermentation-made molecule to market involves multiple stages; the focus of this project is the "select target" phase

Objective

To develop a structured framework to identify viable target molecules for near-term market entry.

Purpose

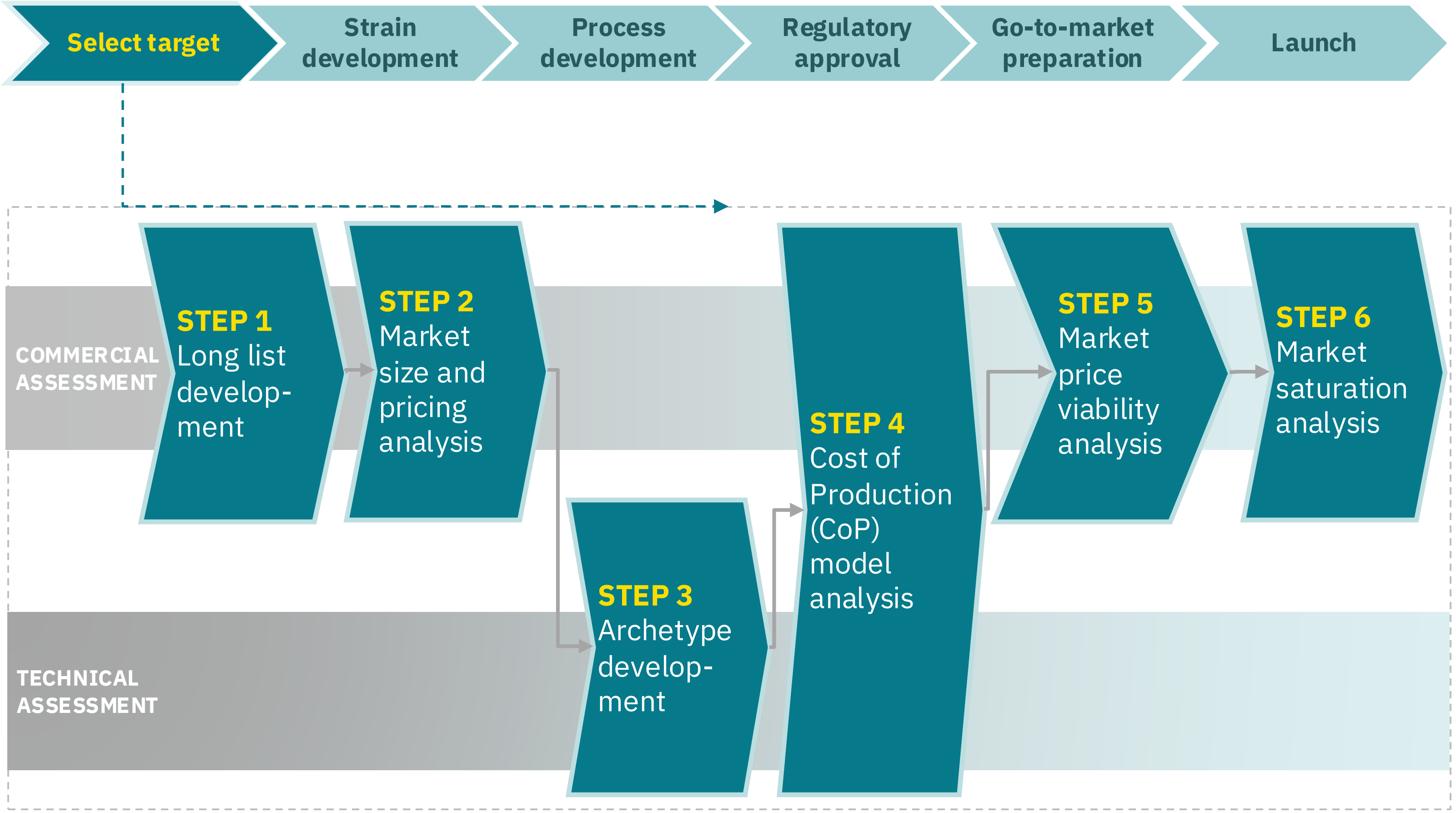
A rigorous target selection process ensures R&D and investment are aligned with viable market opportunities.

Approach

1. Assessing a wide landscape of ingredients that can benefit from PF production.
2. Assessments across both the commercial and technical aspects of a molecule.
3. Conducting deeper techno-economic and market analyses of high potential molecules.

Methodology

Data collection and interviews.



Select target

Strain development

Process development

Regulatory approval

Go-to-market preparation

Launch

COMMERCIAL ASSESSMENT

TECHNICAL ASSESSMENT

STEP 1 Long list development

STEP 2 Market size and pricing analysis

STEP 3 Archetype development

STEP 4 Cost of Production (CoP) model analysis

STEP 5 Market price viability analysis

STEP 6 Market saturation analysis

Step 1: Longlist development

A longlist of 67 molecules was developed with a focus on molecules with a food-specific applications and existing markets, and included both mass market and premium targets

Longlist inclusion

Priority was given to:

- Molecules primarily used in food applications, including proteins, fats and lipids, and small molecules (eg, flavour and aroma compounds, colourants). *Deprioritised molecules include vitamins, bioactive compounds, nutraceuticals, and processing-related ingredients (preservatives, antimicrobials, enzymes).*
- Molecules with existing markets.
- Molecules with readily available market information.

Longlist of molecules

1. Brazzein
2. Leghemoglobin
3. Monellin
4. Myoglobin
5. Casein
6. Chymosin
7. Collagen
8. Glycomacropeptide (GMP)
9. Ovalbumin
10. Thaumatin
11. α-lactalbumin (food-grade)
12. β-lactoglobulin (food-grade)
13. Avidin
14. Lysozyme
15. Elastin
16. Fibronectin
17. Phosvitin
18. Tropoelastin
19. Vitellogenin
20. Albumin (Human & Bovine)
21. Conalbumin/ Ovotransferrin
22. Immunoglobulins (IgG, IgA)
23. Lactoferrin
24. Milk Fat Globule Membrane
25. Ovomucoid
26. α-lactalbumin (high purity)
27. β-lactoglobulin (high purity)
28. Lauric Acid
29. Myristic and Palmitic Acids
30. Oleic Acid
31. Stearic Acid
32. Triacylglycerols
33. Lecithin
34. Ceramides
35. Sphingolipids
36. Omega-6 Fatty Acids
37. Monoolein
38. Monostearin
39. Phospholipids
40. Phosphatidylcholine
41. Phosphatidylethanolamine
42. DHA
43. EPA
44. Benzaldehyde
45. Citronellal
46. Cinnamaldehyde
47. Ethyl Butyrate
48. Ethyl Acetate
49. Eugenol
50. Geraniol
51. Isoamyl Acetate
52. Linalool
53. Limonene
54. Menthone
55. Methyl Salicylate
56. α-Ionene
57. Ethyl Maltol
58. Glutamate
59. Menthol
60. 2-Phenylethanol
61. Vanillin
62. Capsaicin
63. Carotenoids
64. Carminic Acid
65. Inosinate & Guanylate
66. Steviol Glycosides
67. Anthocyanin

Proteins

Fats & lipids

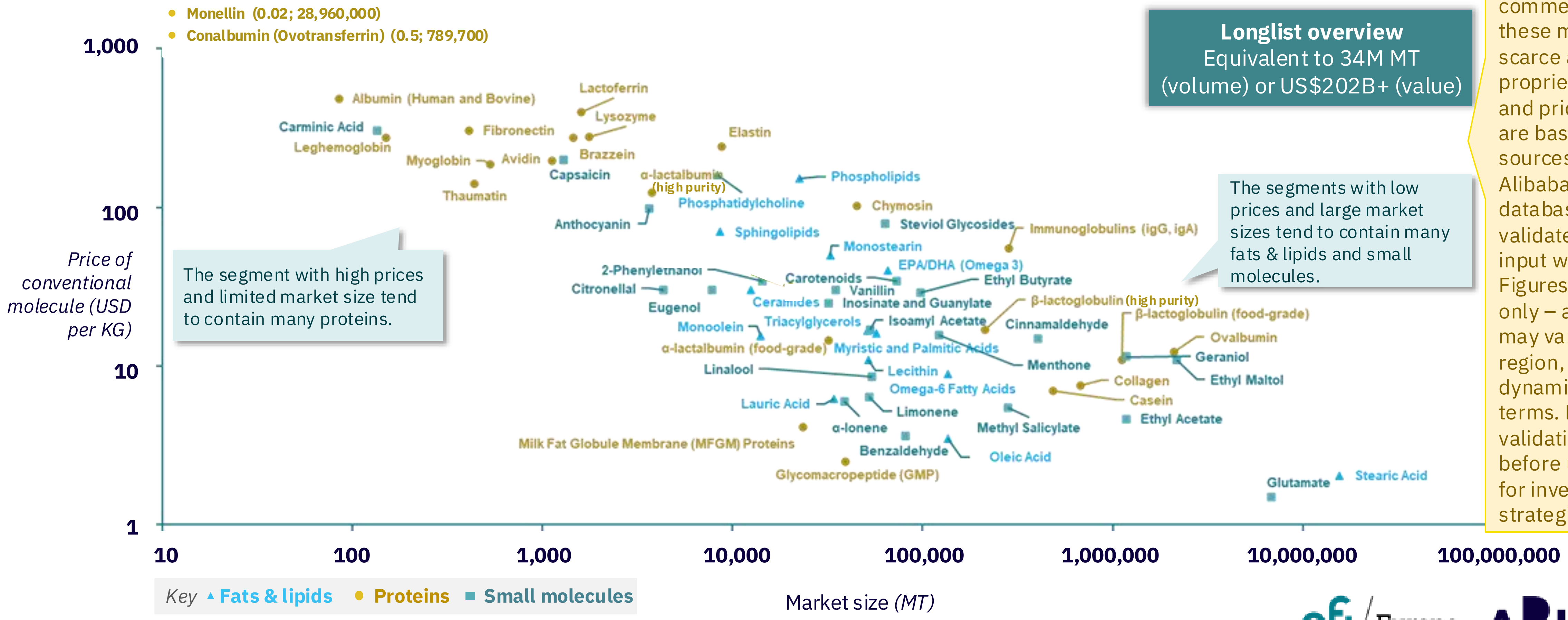
Small molecules

Note: The α-lac and β-lac markets are split by purity grade because these segments are relatively well-characterised and materially distinct in terms of price.

Step 2: Market size and pricing analysis

The market size and market price of each molecule was mapped to signal the viable PF market opportunity, with molecules that have lower prices per kg tending to have larger market sizes

Market size and market price



Longlist overview
Equivalent to 34M MT (volume) or US$202B+ (value)

The segment with high prices and limited market size tend to contain many proteins.

The segments with low prices and large market sizes tend to contain many fats & lipids and small molecules.

Note: Reliable commercial data for these molecules is scarce and often proprietary. Market size and pricing estimates are based on secondary sources (eg,, Volza, Alibaba, trade databases) and validated by expert input where possible. Figures are directional only – actual prices may vary widely by region, buyer-supplier dynamics, and contract terms. Further validation is needed before using this data for investment or strategic decisions.

Note: See appendix slides for exact market size and price per molecule
Source: Arthur D. Little, Sigma-Aldrich, Volza, Alibaba, USTIC, USDA, Mintec

Step 3: Archetype development

To facilitate assessing 67 molecules for technical feasibility, molecules were grouped into archetypes based on similar process configurations, input requirements, and cost drivers

Worked example: Archetype “P1”

The **Protein 1 (P1) archetype** includes the molecules **brazzein, leghemoglobin, monellin, and myoglobin.** These molecules can be grouped together in an archetype because they have similar technical dimensions that determine host strains and process configurations with comparable cost contributions.

Archetype		Relevant dimensions to evaluate technical feasibility			# of molecules from longlist	Molecules from longlist
		Base molecular features	Molecular complexity	Use cases		
Proteins	1	Intracellularly-secreted	Low complexity	Food-grade purity required	4	Brazzein Leghemoglobin Monellin Myoglobin

Likely host strain(s)		Downstream processing configurations							
		Lysis	Centrifuge	(Micro) filtration	Solvent extraction	Phase separation	Chroma-tography	Ultra/dia-filtration	Drying
B	Y	✓	✓	✓	NA	NA		✓	✓

***Key** Bacteria | Yeast | Filamentous fungi

Source: Arthur D. Little

Step 3: Archetype development

Definitions of the technical dimensions and their implications are outlined below

Relevant dimensions to evaluate technical feasibility

Base molecular features

Intracellularly-secreted | **Extracellularly-secreted**

Polar | **Amphiphilic** | **Non-polar**

Intracellular: likely to require cell lysis

Extracellular: less likely to require cell lysis

Polar: likely to require filtration and drying

Amphiphilic: likely to require filtration, phase separation and drying

Non-polar: likely to require phase separation

Molecular complexity

Low complexity

(no/few functional groups, chirality, PTMs[1], or other ligand-binding/folding requirements and complexities)

More likely to support bacterial or yeast-based hosts

High complexity

(many functional groups, chirality, PTMs[1], or other ligand-binding/folding requirements and complexities)

More likely to require yeast or filamentous fungi-based hosts

Use cases

Food-grade purity required

Less likely to require chromatography

High purity required

More likely to require chromatography

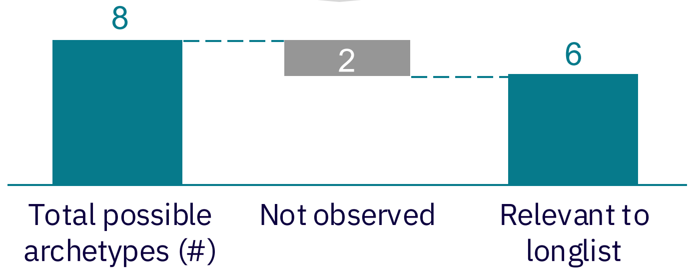
Notes: [1]Post-translational modifications; Source: Arthur D. Little

Step 3: Archetype development

Evaluating the technical dimensions yielded 48 possible archetypes, of which 21 were relevant to the molecules in the longlist

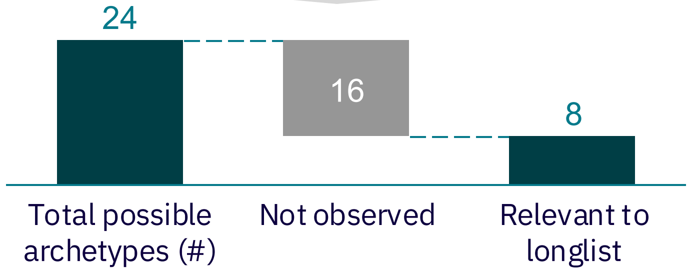
Proteins

- Base molecular features *(Intra or extracellular)*
- Molecular complexity *(high/low)*
- Use case – purity Level *(high/food-grade)*



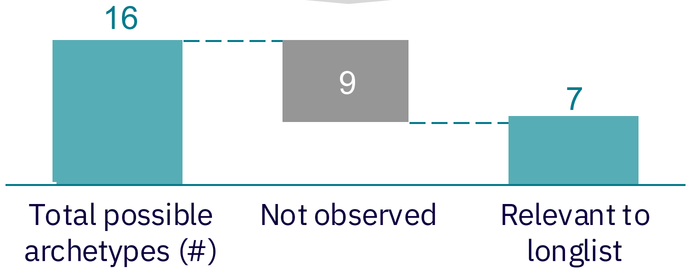
Fats & lipids

- Base molecular features *(Intra or extracellular)*
- Base molecular features *(polar, non-polar, amphiphilic)*
- Molecular complexity *(high/low)*
- Use case – purity Level *(high/food-grade)*



Small molecules

- Base molecular features *(Intra or extracellular)*
- Base molecular features *(polar, non-polar)*
- Molecular complexity *(high/low)*
- Use case – purity level *(high/food-grade)*



Source: Arthur D. Little

Step 3: Archetype development

The 21 relevant archetypes are presented below

Molecule group	Arche type	Relevant dimensions to evaluate technical feasibility				# of molecules from longlist	Example molecule from longlist
		Base molecular features		Molecular complexity	Use cases		
Proteins	1	Intracellularly-secreted		Low complexity	Food-grade purity required	4	Myoglobin
	2	Extracellularly-secreted		High complexity	Food-grade purity required	8	Thaumatin
	3	Intracellularly-secreted		Low complexity	High purity required	1	Avidin
	4	Extracellularly-secreted		Low complexity	High purity required	1	Lysozyme
	5	Intracellularly-secreted		High complexity	High purity required	5	Fibronectin
	6	Extracellularly-secreted		High complexity	High purity required	8	α-lactalbumin
Fats & lipids	1	Intracellularly-secreted	Non-polar	Low complexity	Food-grade purity required	4	Oleic acid
	2	Intracellularly-secreted	Non-polar	High complexity	Food-grade purity required	1	Triacylglycerols
	3	Intracellularly-secreted	Amphiphilic	High complexity	Food-grade purity required	1	Lecithin
	4	Extracellularly-secreted	Polar	High complexity	Food-grade purity required	2	Sphingolipids
	5	Extracellularly-secreted	Non-polar	Low complexity	High purity required	1	Omega-6 fatty acids
	6	Extracellularly-secreted	Amphiphilic	Low complexity	High purity required	2	Monostearin
	7	Intracellularly-secreted	Amphiphilic	High complexity	High purity required	3	Phospholipids
	8	Extracellularly-secreted	Polar	High complexity	High purity required	2	DHA
Small molecules	1	Extracellularly-secreted	Non-polar	Low complexity	Food-grade purity required	13	Benzaldehyde
	2	Intracellularly-secreted	Polar	Low complexity	Food-grade purity required	3	2-Phenylethanol
	3	Intracellularly-secreted	Non-polar	High complexity	Food-grade purity required	1	Menthol
	4	Intracellularly-secreted	Polar	Low complexity	High purity required	1	Vanillin
	5	Intracellularly-secreted	Non-polar	High complexity	High purity required	2	Carotenoids
	6	Intracellularly-secreted	Polar	High complexity	High purity required	3	Carminic acid
	7	Extracellularly-secreted	Polar	High complexity	High purity required	1	Anthocyanin

Source: Arthur D. Little

Step 3: Archetype development

Each archetype also considered likely host strain(s) and downstream processing configurations, which heavily influence efficiency and costs

Molecule group	Arche type	Likely host strain(s)*		Downstream processing configurations							
				Lysis	Centrifuge	(Micro) filtration	Solvent extraction	Phase separation	Chroma-tography	Ultra/dia-filtration	Drying
Proteins	1	B	Y	✓	✓	✓	NA	NA		✓	✓
	2	Y	F			✓	NA	NA		✓	✓
	3	B	Y	✓	✓	✓	NA	NA	✓	✓	✓
	4	B	Y			✓	NA	NA	✓	✓	✓
	5	Y	F	✓	✓	✓	NA	NA	✓	✓	✓
	6	Y	F			✓	NA	NA	✓	✓	✓
Fats & lipids	1	B	Y	✓	✓		✓	✓		NA	
	2	Y	F	✓	✓		✓	✓		NA	
	3	Y	F	✓	✓	✓	✓	✓		NA	✓
	4	Y	F		✓	✓	✓			NA	✓
	5	B	Y		✓		✓	✓	✓	NA	
	6	B	Y		✓	✓	✓	✓	✓	NA	✓
	7	Y	F	✓	✓	✓	✓	✓	✓	NA	✓
	8	Y	F		✓	✓	✓		✓	NA	✓
Small molecules	1	B	Y		✓		✓	✓		NA	
	2	B	Y	✓	✓	✓				NA	✓
	3	Y	F	✓	✓		✓	✓		NA	
	4	B	Y	✓	✓	✓			✓	NA	✓
	5	Y	F	✓	✓		✓	✓	✓	NA	
	6	Y	F	✓	✓	✓			✓	NA	✓
	7	Y	F		✓	✓			✓	NA	✓

Notes: For more information on host strains, see Eastham and Leman (2024); Source: Arthur D. Little

***Key** | Bacteria | Yeast | Filamentous fungi

Step 4: Cost of Production (CoP) model analysis

A CoP model was developed for each archetype to provide insight into the estimated costs of production via precision fermentation for molecules in that archetype

A precision fermentation-made molecule production cost range was estimated for each archetype, representing the estimated **cost per kg to produce molecules in that archetype.**

Molecules within the same archetype are assumed to share **similar process configurations, input requirements, and cost drivers.** The cost estimates for each archetype are based on assumptions about the typical host strains used (eg, fungi, bacteria) and the necessary upstream and downstream equipment and process setups to produce those molecules.

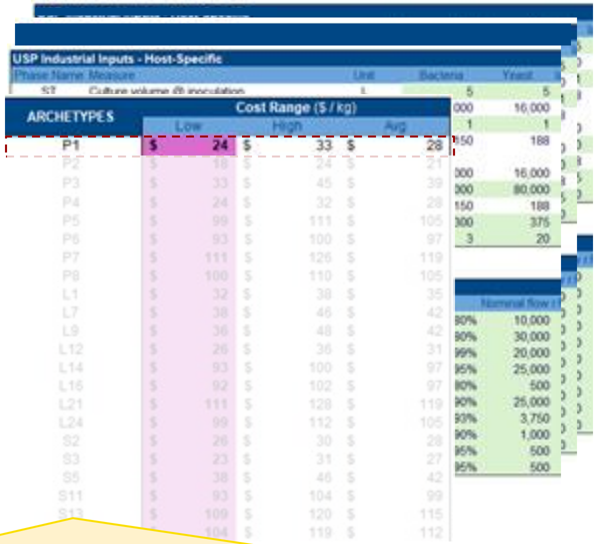
Example: Deriving assumptions to inform the CoP model for the "P1" archetype

For the **P1 archetype**, the CoP model incorporated cost assumptions that were derived from the technical dimensions, likely host strains, and process configurations shared by molecules in the archetype. This resulted in an **estimated production cost of $24-$33/kg** for precision fermentation-made P1 molecules.

Archetype		Technical dimensions		
		Base molecular features	Molecular complexity	Use cases
Proteins	1	Intracellularly-secreted	Low complexity	Food-grade purity required

- Myoglobin
- Brazzein
- Leghemoglobin
- Monellin

Likely host strain(s)*		Downstream processing configurations				
		Lysis	Centrifuge	(Micro) filtration	Ultra/dia-filtration	Drying
B	Y	✓	✓	✓	✓	✓



USP Industrial Inputs - Host-Specific

Phase Name Measure Unit Bacteria Yeast

S1 Culture volume @ inoculation L 5 5

ARCHETYPES	Cost Range ($ / kg)		
	Low	High	Avg
P1	$ 24	$ 33	$ 28
P2	$ 18	$ 24	$ 21
P3	$ 33	$ 45	$ 39
P4	$ 24	$ 32	$ 28
P5	$ 99	$ 111	$ 105
P6	$ 93	$ 100	$ 97
P7	$ 111	$ 126	$ 119
P8	$ 100	$ 110	$ 105
L1	$ 32	$ 38	$ 35
L7	$ 38	$ 46	$ 42
L9	$ 36	$ 48	$ 42
L12	$ 26	$ 36	$ 31
L14	$ 93	$ 100	$ 97
L16	$ 92	$ 102	$ 97
L21	$ 111	$ 128	$ 119
L24	$ 99	$ 112	$ 105
S2	$ 26	$ 30	$ 28
S3	$ 23	$ 31	$ 27
S5	$ 38	$ 46	$ 42
S11	$ 93	$ 104	$ 99
S13	$ 109	$ 120	$ 115
	$ 104	$ 119	$ 112

Note: The CoP model is a tool for obtaining directional estimates of unit economics based on input assumptions. It is designed to test archetypes and enable sensitivity analysis by assessing cost variations based on input changes. It is not a precise or definitive predictor of molecule production costs. Actual costs require company-specific, real-world data.

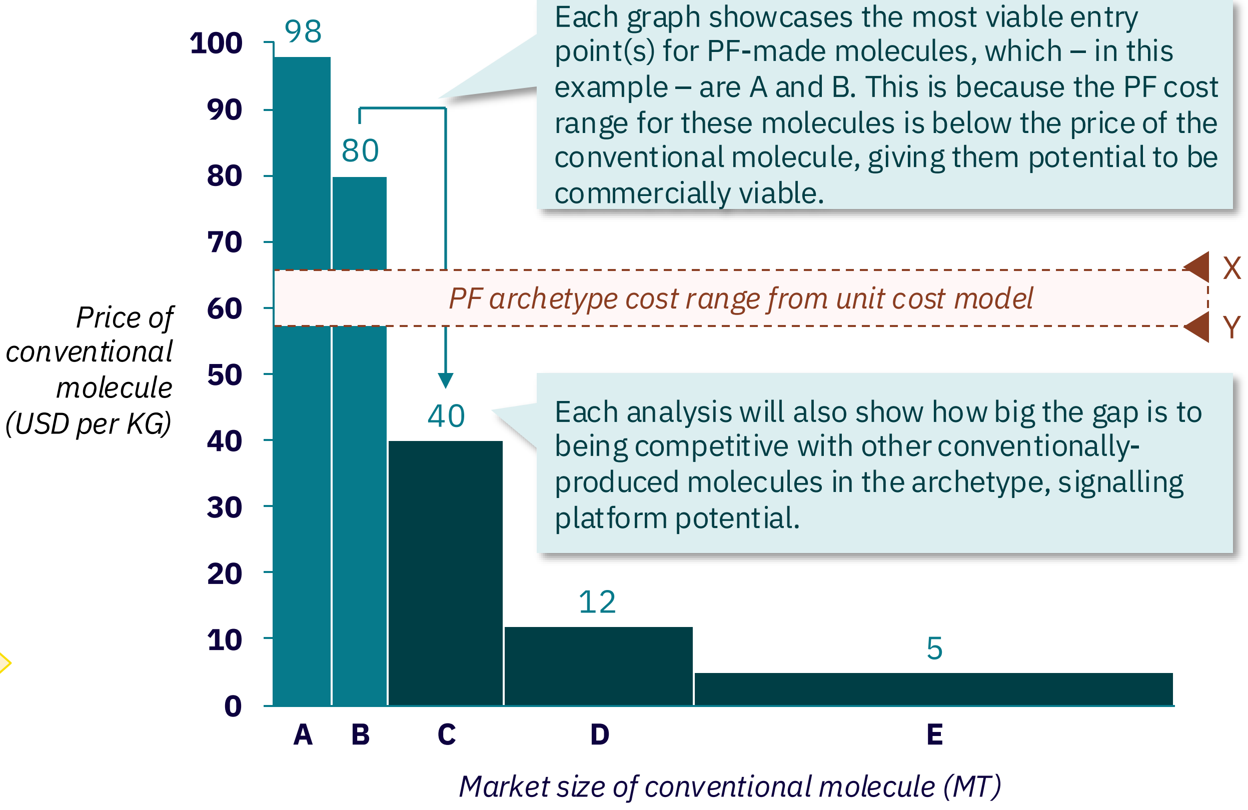
Step 5: Market price viability analysis

By combining the market size and price information for each molecule from step 2 with the cost estimates per archetype from step 4, molecules were evaluated for their market potential

The market opportunity for each PF-made molecule was estimated by **comparing the estimated PF production cost** (based on the CoP model) to the **market size and price of the conventionally-made molecule** (based on market data). For each molecule, data was gathered from three sources – triangulated across trade databases, e-commerce platforms, market research reports, and news articles – and averaged to produce indicative price and volume estimates.

The example graph to the right outlines how the price and cost estimate analysis of each archetype was developed. The following section presents two archetypes for illustration and the final list of prioritised molecules.

"Cost vs price" disclaimer: Comparing modelled cost of production (CoP) to market prices can provide a useful benchmark for assessing cost competitiveness. However, CoP and market price are not equivalent. CoP reflects the capital and operational expenses associated with producing a product, whereas market price captures the full cost of goods sold (COGS) and incorporates additional downstream costs and profit margins applied throughout the value chain. As such, comparisons should not be assumed to represent direct parity.



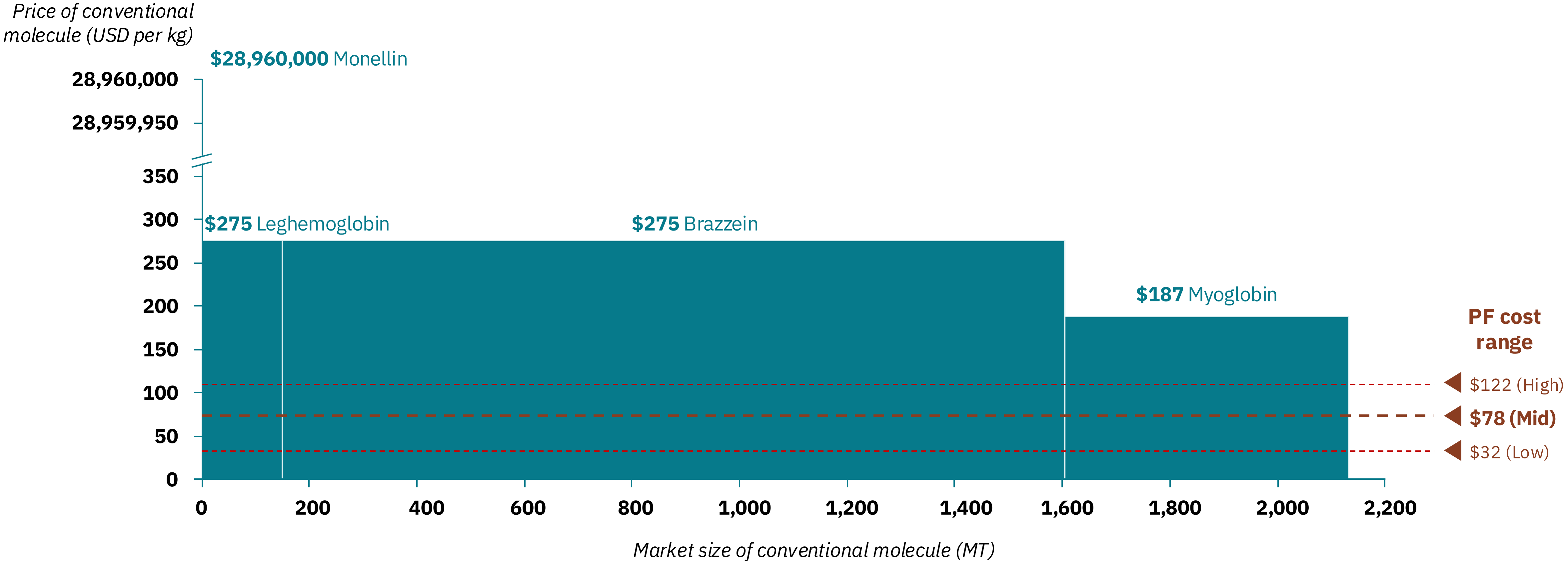
Each graph showcases the most viable entry point(s) for PF-made molecules, which – in this example – are A and B. This is because the PF cost range for these molecules is below the price of the conventional molecule, giving them potential to be commercially viable.

Each analysis will also show how big the gap is to being competitive with other conventionally-produced molecules in the archetype, signalling platform potential.

Step 5: Market price viability analysis

All the molecules in the P1 archetype appear to be strong candidates, with production costs below the conventional market price, leaving room for additional market entry costs

Example of market price viability analysis: “P1” archetype

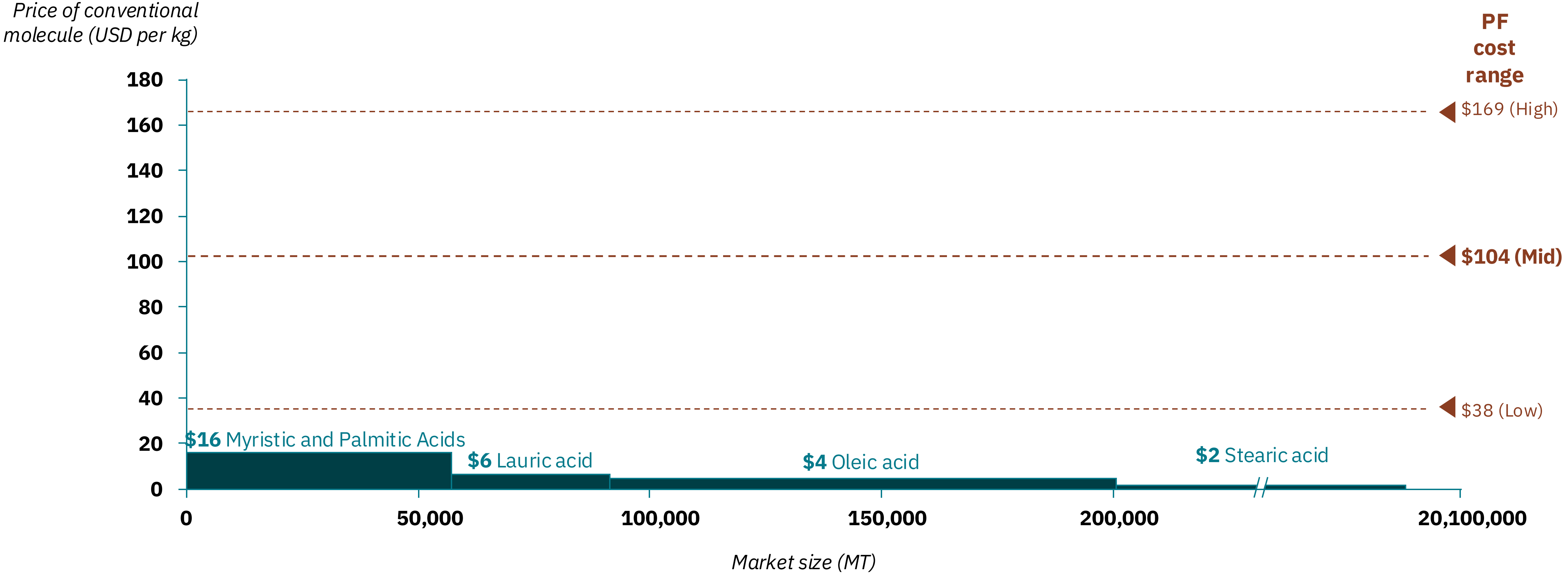


Source: Arthur D. Little

Step 5: Market price viability analysis

None of the molecules under Archetype L1 can be considered to have potential due to the low price point of the existing products

Example of market price viability analysis: “L1” archetype



Source: Arthur D. Little

Step 5: Market price viability analysis

Of the original 67 molecules on the longlist, 16 of the PF-made molecules have a potentially viable price point for market entry

Summary of prioritised molecules

P1	**Brazzein**
	Leghemoglobin
	Monellin
	Myoglobin
P2	Casein
	Chymosin
	Collagen
	Glycomacropeptide (GMP)
	Ovalbumin
	Thaumatin
	α-lactalbumin (food-grade)
	β-lactoglobulin (food-grade)
P3	**Avidin**
P4	**Lysozyme**
P5	**Elastin**
	Fibronectin
	Phosvitin¹
	Tropoelastin¹
	Vitellogenin¹
P6	**Albumin (Human & Bovine)**
	Conalbumin/Ovotransferrin
	Immunoglobulins (IgG, IgA)
	Lactoferrin
	Milk Fat Globule Membrane
	Ovomucoid¹
	α-lactalbumin (high purity)
	β-lactoglobulin (high purity)
L1	Lauric Acid
	Myristic and Palmitic Acids
L1	Oleic Acid
	Stearic Acid
L2	Triacylglycerols
L3	Lecithin
L4	Ceramides
	Sphingolipids
L5	Omega-6 Fatty Acids
L6	Monoolein
	Monostearin
L7	**Phospholipids**
	Phosphatidylcholine
	Phosphatidylethanolamine
L8	DHA
	EPA
S1	Benzaldehyde
S1	Citronellal
	Cinna
	Ethyl E
	Ethyl A
	Eugen
	Gerani
	Isoamyl Acetate
	Linalool
	Limonene
	Menthone
	Methyl Salicylate
	α-Ionene
S2	Ethyl Maltol
	Glutamate
	2-Phenylethanol
S3	Menthol
	Stevio
S7	Anthocyanin

Note: The precision fermentation-made production cost of small molecules was not possible to estimate as a group due to markedly different expression systems, titres, and downstream processing methods. As a result, the model's underlying assumptions do not apply reliably, and they have therefore been excluded from further analysis.

Legend:

Potential entry point	
PX	Protein archetypes
LX	Fat & lipid archetypes
SX	Small molecule archetypes

Note: ¹Molecule excluded due to lack of market size or price data information; Source: Experts interviews, desktop research, Arthur D. Little

Step 6: Market saturation analysis

To further understand the market potential of the 16 molecules, a market saturation analysis was conducted to analyse existing market players and the impact of a new PF plant

Note: Modelled plant size reflects a conservative, first-of-a-kind (FOAK) facility suitable for niche market entry. While this may inflate cost estimates, it helps illustrate market saturation potential at modest volumes.

1 Magnitude of presence of existing players

- The magnitude of the presence of existing players in each PF-made molecule market was evaluated, considering the size and number of companies.

- Larger companies were assumed to have greater manufacturing capacity and were assigned a higher weight during the evaluation.

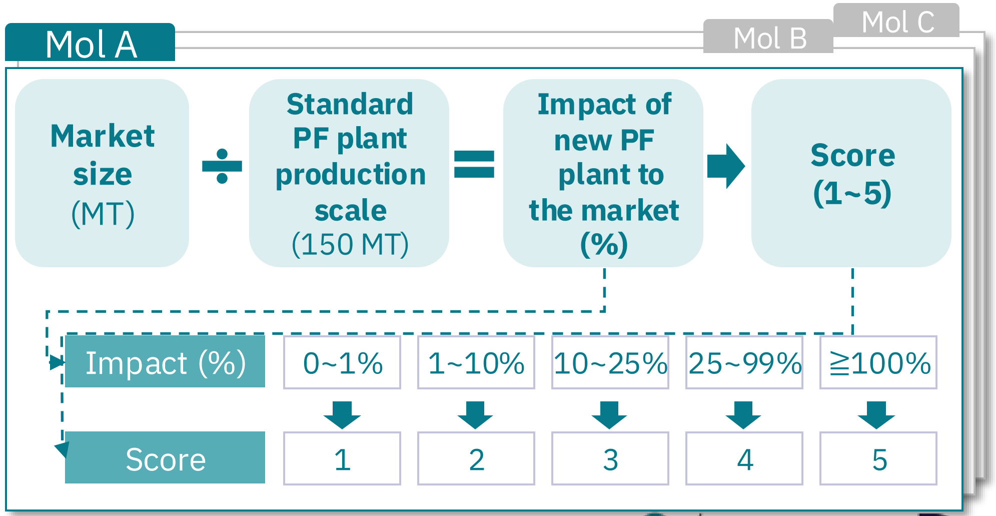
Mol A Mol B Mol C

	Weight	✖	No of companies	=	Score
Corporate	4	✖	n	=	4n
Startup	1	✖	n	=	1n

2 Impact of new PF plant to the market

- The number of new entrants a market can accommodate was evaluated based on the impact of a new PF plant (150 MT) in the market.

- If the impact of a single plant is minimal, the market can support a larger number of entrants, leading to the conclusion that market saturation is low.



Mol A Mol B Mol C

Market size (MT) ÷ **Standard PF plant production scale** (150 MT) = **Impact of new PF plant to the market (%)** ➡ **Score (1~5)**

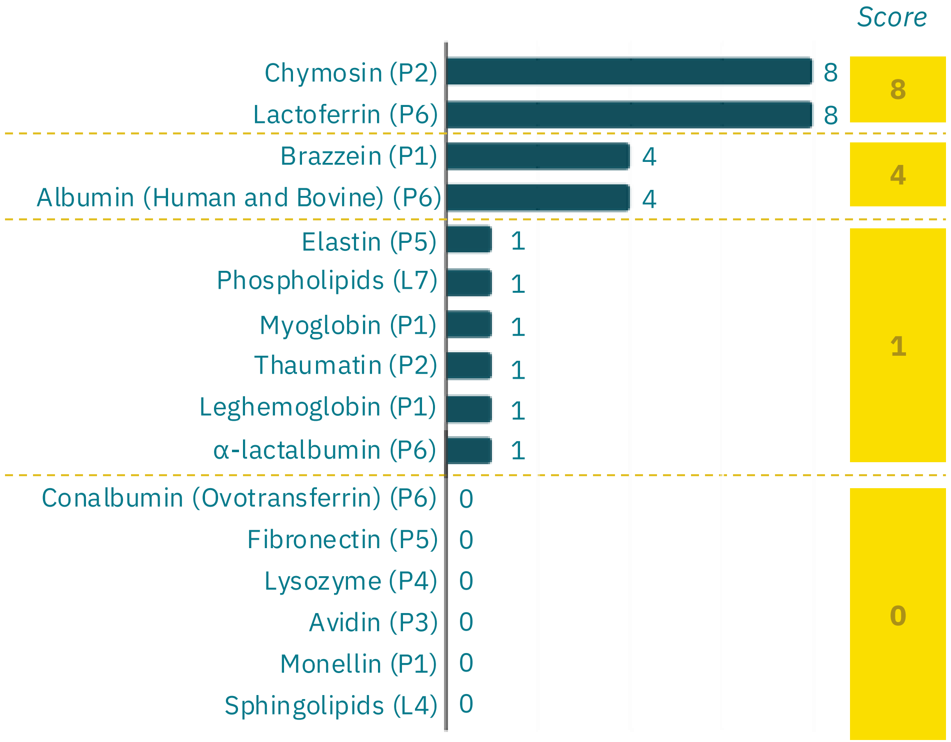
Impact (%)	0~1%	1~10%	10~25%	25~99%	≧100%
Score	1	2	3	4	5

Notes: Databases analyzed includes US FDA GRAS, EU Novel Food Status Catalogue, AgFunder, Protein Directory, Ingredients Network, GFI Company database

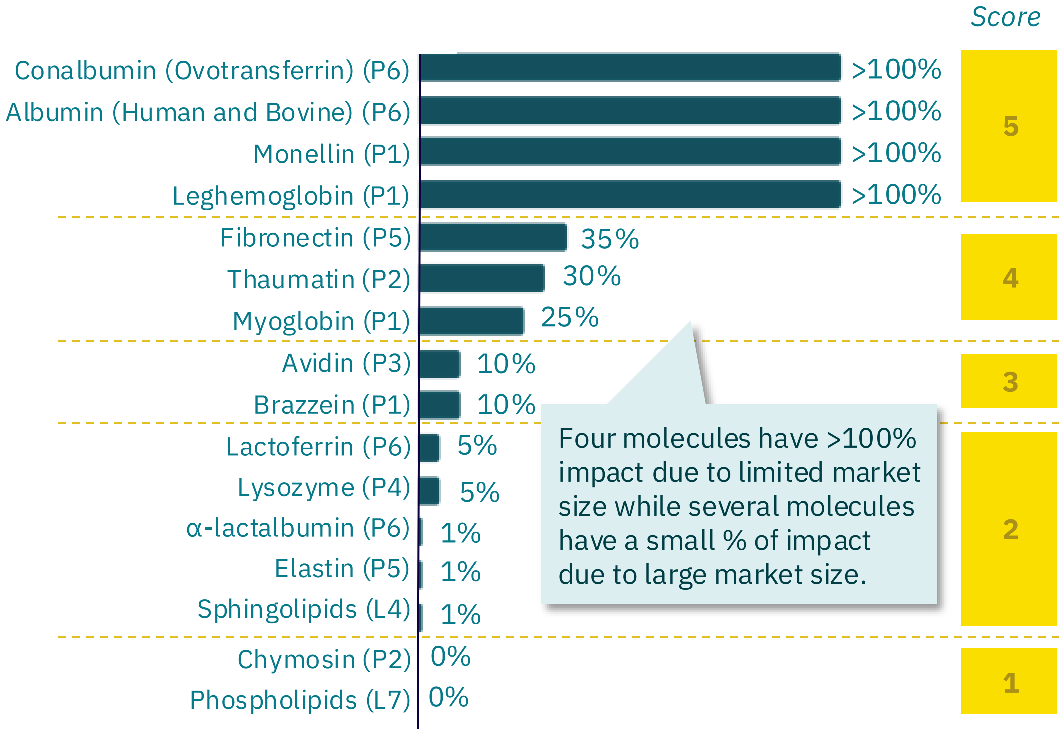
Step 6: Market saturation analysis

Each molecule was scored according to the magnitude of presence of existing players in the market, and the impact of a new PF plant to the market

1 Magnitude of presence of existing players



2 Impact of new PF plant to the market



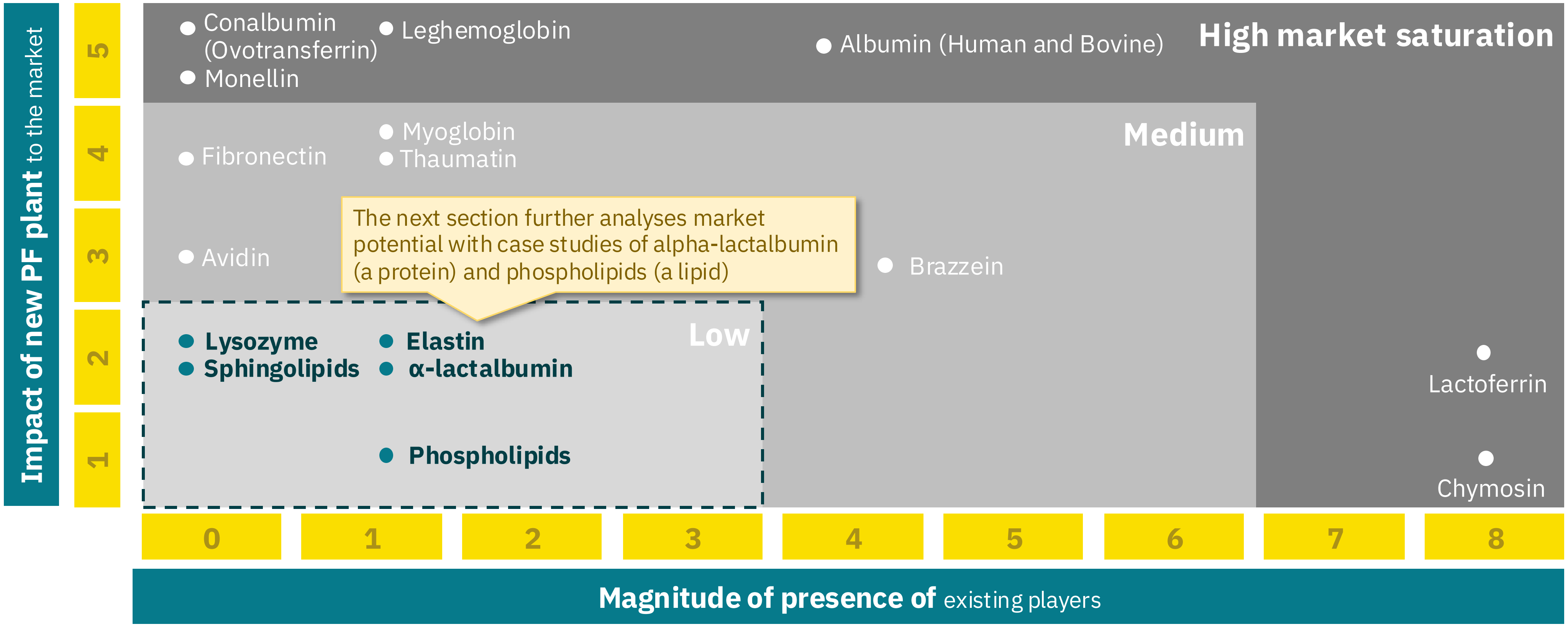
Four molecules have >100% impact due to limited market size while several molecules have a small % of impact due to large market size.

Note: See appendix for list of companies identified in "magnitude of presence of existing players" exercise
Source: Arthur D. Little

Step 6: Market saturation analysis

All 16 prioritised molecules have market entry potential; understanding the market saturation provides an additional lens to take into consideration when developing market entry strategies

Results of market saturation analysis for the 16 shortlisted molecules



The next section further analyses market potential with case studies of alpha-lactalbumin (a protein) and phospholipids (a lipid)

Source: Arthur D. Little

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Alpha-lactalbumin case study

Summary of key findings

Properties

Description

Alpha-lactalbumin (α-lac) is a whey protein found in cow's milk.

Key properties

- **Functional qualities**
  - Stabiliser
  - Water binding and solubility
  - Ion binding and stability
- **Nutritional qualities**
  - Essential amino acids
  - Tryptophan provider
  - Antioxidant
  - Immune Support

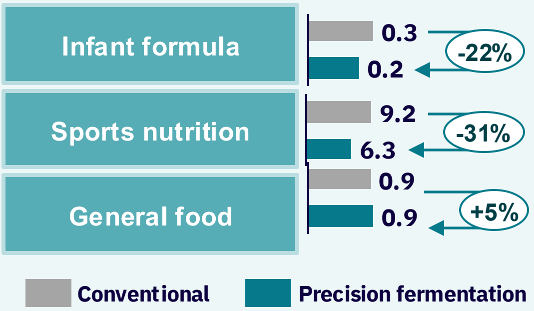
Applications

- **Food**
  - Infant formula
  - Sports nutrition
  - General food
- **Cosmetics and skincare**
- **Health supplements**

Cost comparison

The cost of PF-nmade α-lac was estimated using the CoP model and compared with the conventionally-made molecule's market price.

- On a cost of molecule basis (USD per kg of molecule) PF-made α-lac may be cost-competitive for infant nutrition and sports nutrition, and even more competitive on a cost-in-use basis.
- For general food applications, further cost reductions are needed to compete on price.


Cost-in-use comparison (USD/kg)

Market opportunity

The CoP model estimated changes to the cost of production based on improvement scenarios in four key areas (culture volume at harvest, target yield on substrate, substrate cost, and titre at harvest).

- With 50% improvement in the four key cost drivers, the PF-made α-lac unit cost declines:
  - For food-grade purity, from **$24/kg to $12/kg**.
  - For high purity, from **$100/kg to $86/kg**.
- The market size for high purity α-lac is ~3,700 MT. If the technical platform for α-lac can be used to produce other molecules in the same archetype, the market opportunity expands to **51,000 MT (13x bigger than α-lac)**.

Alpha-lactalbumin case study

As seen on slide 21, α-lac is part of both the P2 and P6 archetypes of protein molecules depending on the purity level

Archetype

Proteins "P2"

- **Alpha-lactalbumin *(food-grade)***
- Beta-lactoglobulin *(food-grade)*
- Casein
- Chymosin
- Collagen
- Glycomacropeptide
- Ovalbumin
- Thaumatin

Technical dimensions

Base molecular features	Molecular complexity	Use cases
Extracellularly-secreted	High complexity	Food-grade purity required

Downstream processing configurations

Likely host strain(s)*		Lysis	Centrifuge	(Micro) filtration	Solvent extraction	Phase separation	Chroma-tography	Ultra/dia-filtration	Drying
Y	F			✓	NA	NA		✓	✓

Archetype

Proteins "P6"

- **Alpha-lactalbumin *(high purity)***
- Beta-lactoglobulin (high purity)
- Albumin (Human & Bovine)
- Conalbumin/Ovotransferrin
- Immunoglobulins (IgG, IgA)
- Lactoferrin
- Milk Fat GLobule Membrane
- Ovomucoid

Technical dimensions

Base molecular features	Molecular complexity	Use cases
Extracellularly-secreted	High complexity	High purity required

Downstream processing configurations

Likely host strain(s)*		Lysis	Centrifuge	(Micro) filtration	Solvent extraction	Phase separation	Chroma-tography	Ultra/dia-filtration	Drying
Y	F			✓	NA	NA	✓	✓	✓

Alpha-lactalbumin case study

There are three potential market segments that differ based on purity levels; precision fermentation-derived α-lac can offer advantages in cost, functionality and purity

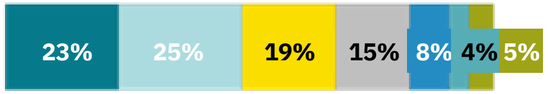
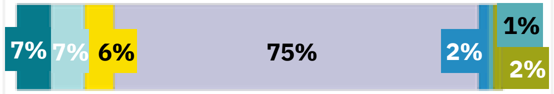
	Key considerations for market entry with PF-made α-lac				
	Affordability	*Safety*	*Nutritional value*	*Functionality*	**Potential PF benefits compared to conventional**
Infant formula	High customer willingness to pay	No tolerance policy (zero for pathogens[1], stricter than food for other[2])	High impact on infant body and brain development	Limited infant digestibility	✓ Possibly cheaper than conventional production ($100/kg vs $123/kg) ✓ Comparable nutritional value ✓ Potential functional advantages (eg, solubility) ✓ Higher purity ✗ Lengthy approval process
Sports nutrition	Medium customer willingness to pay	Medium tolerance (zero for pathogens[1], limits for other[2])	Moderate impact on physical development, sleep, and mood	Minimal texture requirements	✓ Possibly cheaper than conventional production ($24/kg vs $29/kg) ✓ Comparable nutritional value ✓ Potential functional advantages (eg, solubility) ✓ Higher purity
General food	Low customer willingness to pay	Medium tolerance (zero for pathogens[1], limits for other[2])	None	Employed for emulsifying, foaming, etc. capabilities only	✓ Comparable nutritional value ✓ Potential functional advantages (eg, solubility) ✓ Higher purity ✗ No cost or cost-in-use advantage at present

Note: (1) e.g. European Commission set MRLs (Maximum Residue Levels) for pesticide to 0.01mg/kg for general food and <0.01mg/kg for infant formula; (2) e.g., pesticides, heavy metals (e.g., lead, cadmium), microbiological hazards, nitrates. Source: Expert interviews, Green Queen, Arthur D. Little

Alpha-lactalbumin case study

The estimated CoP of PF-made α-lac is ~$24-$100/kg at 80l harvest volume, depending on purity

Base case assumptions for PF-made α-lac

Unit Cost Driver	**Food-grade purity** (~95% ±10%)	**High purity** (>99%)	**Assumption Basis**[1]
Production region	United States		*Arbitrary*
Host type	Yeast		*Industry interviews / triangulation;* *Fermentation. 2024; 10(6):315*
Secretion type	Extracellular		*J Agric Food Chem. 2022 Mar 2;70(8):2664-2672*
Culture volume @ harvest *(m³)*	80		*GFI technical team*
Target yield on substrate *(g/g)*²	0.13		*Sci Rep 6, 36421 (2016);* *Microb Cell Fact **22**, 76 (2023)*
Substrate cost *($/kg)*	$0.60		*Industry interviews / triangulation*
Titre @ harvest *(g/l)*	20		*GFI technical team*
DSP configuration	1. Microfiltration 2. Ultra / diafiltration 3. Spray drying	1. Microfiltration 2. Chromatography 3. Ultra / diafiltration 4. Spray drying	*Industry interviews / triangulation;* *GFI technical team*
DSP yield	87%	70%	
Batch length *(days)*	2.2	2.2	
Batches/year	162	164	
Output product *(kg powder/batch)*	1,400	1,120	
<u>Base</u> unit cost *($/kg)*	**$24**	**$100**	
Breakdown of unit costs			

Sensitivity tested on upcoming slides

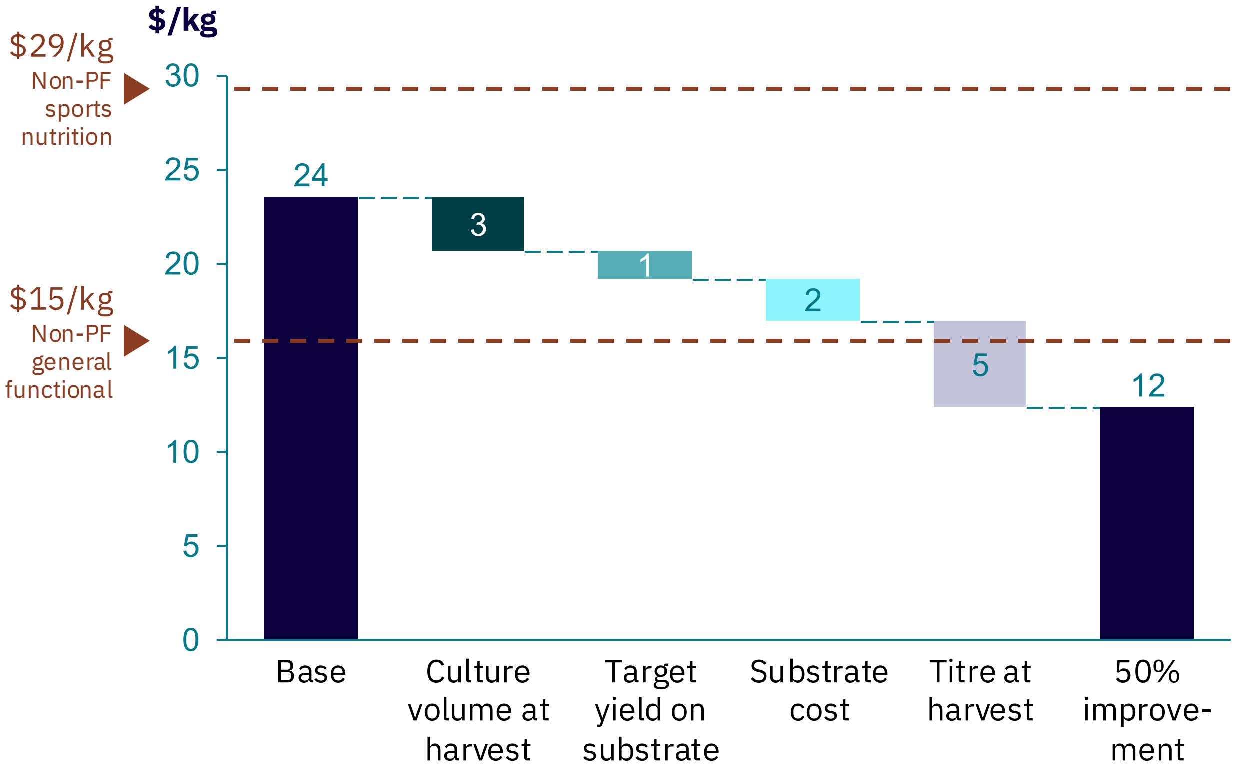
■ *Raw materials*
■ *Labor*
■ *Capex*
■ *Consumables*
■ *Other²*
■ *Maintenance/ Insurance*
■ *Utilities*

Note: (1) Values observed in real-world, scaled precision fermentation production may differ notably from "base" assumptions which are meant to provide an initial basis for sensitivity analyses rather than an authoritative, precise estimate of real-world production costs. (2) Grams of target molecule (α-lac in this case) per gram of non-water media additive (sugars, growth factors, buffers, etc.) Includes QC/QA/Laboratory and waste disposal. Source: Arthur D. Little

Alpha-lactalbumin case study

For food-grade purity α-lac, the unit cost declines from $24/kg to $12/kg with improvement in four key cost drivers

Unit cost sensitivities to key variables for food-grade purity α-lac



50% improvement vs "base" assumptions

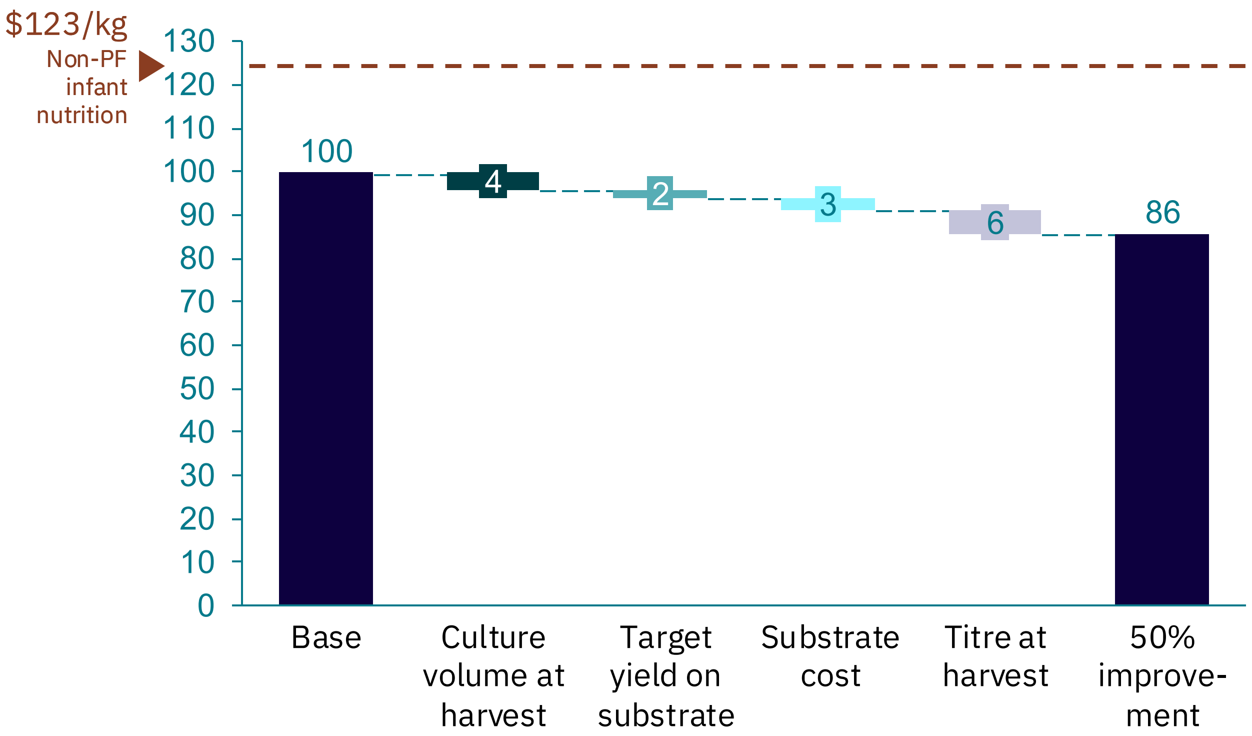
Improvement scenarios		
Variable	Base	50%
Target yield on substrate *(g/g)*[2]	0.13	0.19
Substrate cost *($/kg)*	$0.60 / kg	$0.30 / kg
Culture volume at harvest *(m^3)*	80 m^3	120 m^3
Titre at harvest *(g/L)*	20 g/l Titre	30 g/l Titre
Production cost	**$24**	**$12**

Source: Arthur D. Little

Alpha-lactalbumin case study

For high purity α-lac, the unit cost declines from $100/kg to $86/kg with improvement in four key cost drivers

Unit cost sensitivities to key variables for high purity α-lac



Improvement scenarios		
Variable	Base	50%
Target yield on substrate *(g/g)*[2]	0.13	0.19
Substrate cost *($/kg)*	$0.60 / kg	$0.30 / kg
Culture volume at harvest *(m³)*	80 m³	120 m³
Titre at harvest *(g/L)*	20 g/l Titre	30 g/l Titre
Production cost	**$100**	**$86**

50% improvement vs "base" assumptions

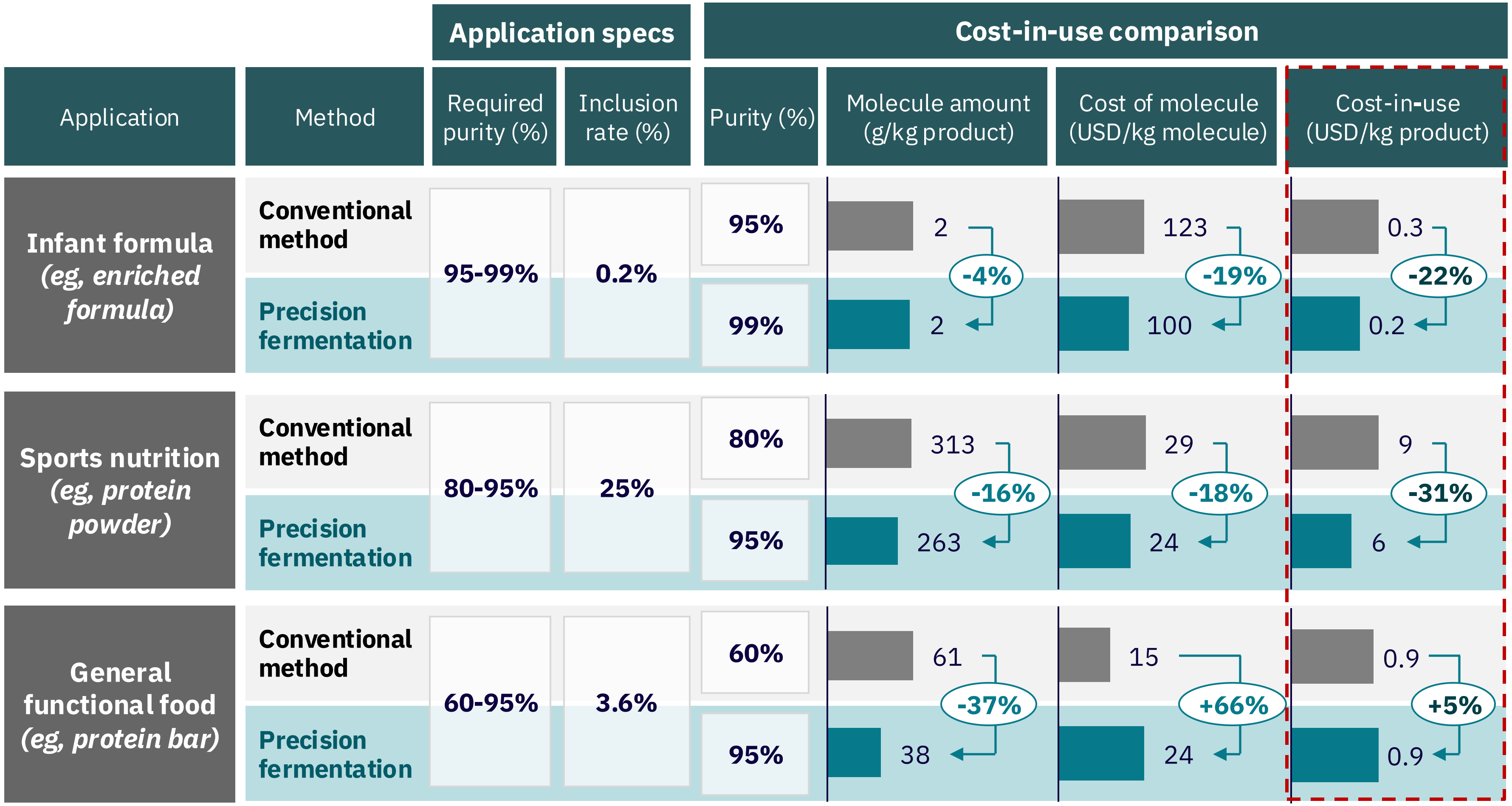
Source: Arthur D. Little

Alpha-lactalbumin case study

On a cost-in-use basis, PF-made α-lac may be even more competitive for infant formula and sports nutrition, while further cost reductions are still needed to compete in general food

The role of cost-in-use

Cost-in-use accounts for the **actual quantity needed to deliver equivalent functionality** – meaning that higher purity or more efficient ingredients can reduce required dosages, lower formulation or processing costs, and ultimately lead to a more competitive total cost.



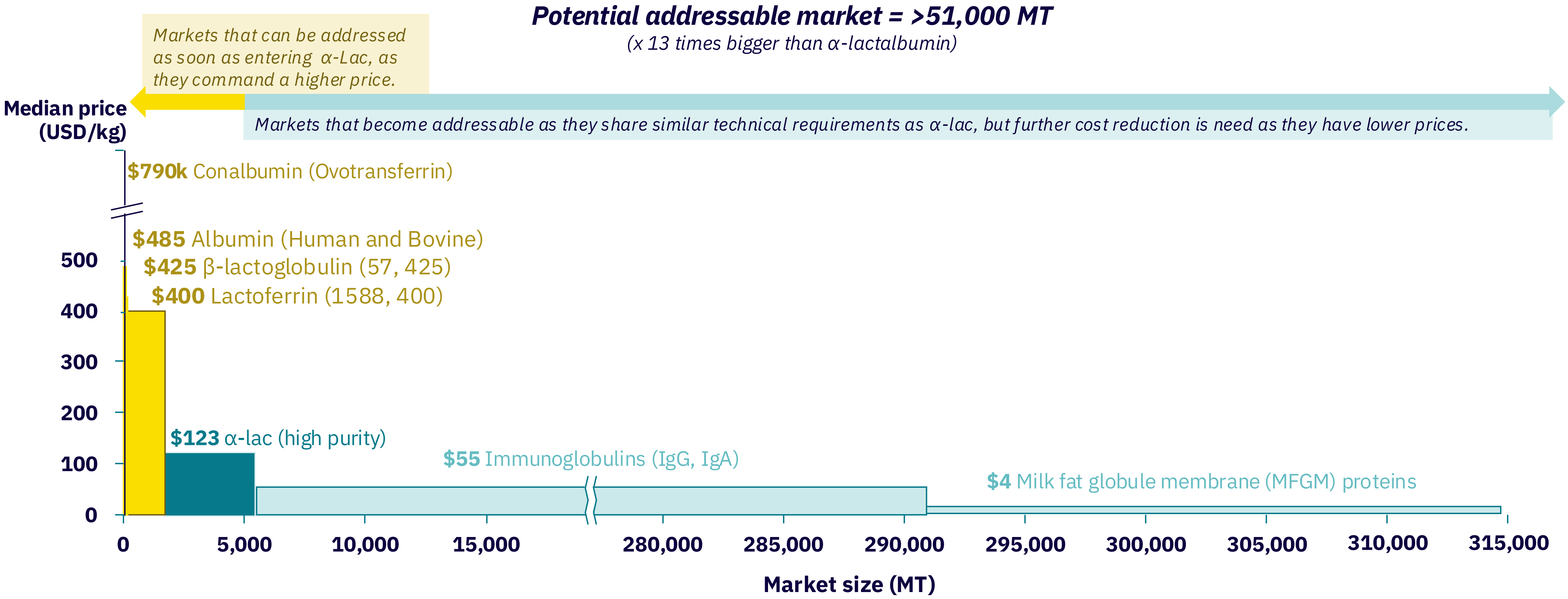
		Application specs		Cost-in-use comparison			
Application	Method	Required purity (%)	Inclusion rate (%)	Purity (%)	Molecule amount (g/kg product)	Cost of molecule (USD/kg molecule)	Cost-in-use (USD/kg product)
Infant formula *(eg, enriched formula)*	**Conventional method**	**95-99%**	**0.2%**	**95%**	2	123	0.3
	Precision fermentation			**99%**	-4% 2	-19% 100	-22% 0.2
Sports nutrition *(eg, protein powder)*	**Conventional method**	**80-95%**	**25%**	**80%**	313	29	9
	Precision fermentation			**95%**	-16% 263	-18% 24	-31% 6
General functional food *(eg, protein bar)*	**Conventional method**	**60-95%**	**3.6%**	**60%**	61	15	0.9
	Precision fermentation			**95%**	-37% 38	+66% 24	+5% 0.9

Source: Arthur D. Little

Alpha-lactalbumin case study

Note: Producing a P6 archetype protein requires nearly the same configuration as proteins in the P2 archetype. If efficiency improvements can be made with the production platform, it may also be feasible to produce some P2 proteins at a viable market price.

If the technical platform used to produce α-lac can be leveraged to address the other molecules under archetype P6, there is a 13x bigger market potential



Potential addressable market = >51,000 MT

(x 13 times bigger than α-lactalbumin)

Markets that can be addressed as soon as entering α-Lac, as they command a higher price.

Markets that become addressable as they share similar technical requirements as α-lac, but further cost reduction is need as they have lower prices.

Notes: Archetype P8 Molecules excluded due to lack of market size or price data: Ovomucoid; Source: Arthur D. Little

Phospholipids case study

Summary of key findings

Properties

Description

Phospholipids are emulsifying and cognition-enhancing nutrients sourced from animals or plants.

Key properties

- **Functional qualities**
  - Emulsifying
  - Preservative
- **Nutritional qualities**
  - Cognition enhancer
  - Immunity enhancer
  - Metabolism facilitator
  - Anti-aging

Applications

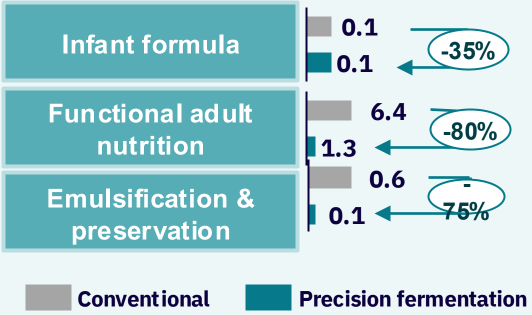
- **Food**
  - Infant formula
  - Functional adult nutrition (eg, "anti-stress")
  - General food functionality enhancer and preservative
- **Cosmetics and pharmaceuticals**

Cost comparison

The cost of PF-made phospholipids was estimated using the CoP model and compared with the conventionally-made molecule's market price.

- On a cost of molecule basis (USD per kg of molecule) and a cost-in-use basis (USD per kg of product) PF-made phospholipids may be cost-competitive for **all three applications**.

Cost-in-use comparison **(USD/KG)**



Market opportunity

The CoP model estimated changes to the cost of production based on improvement scenarios in four key areas (culture volume at harvest, target yield on substrate, substrate cost, and titre at harvest).

- With 50% improvement in the four key cost drivers, the PF-derived α-lac unit cost declines:
  - For lower purity, from **$27/kg to $14/kg.**
  - For high purity, from **$99/kg to $83/kg.**

Phospholipids case study

As seen on slide 21, phospholipids is part of the L7 archetype of fats and lipids molecules depending on the purity level

Archetype	Technical dimensions		
Fats and lipids “L7”	**Base molecular features**	**Molecular complexity**	**Use cases**
	Intracellularly-secreted Amphiphilic	High complexity	High purity required

- **Phospholipids**
- Phosphatidylcholine
- Phosphatidylethanolamine

Likely host strain(s)*		**Downstream processing configurations**							
		Lysis	Centrifuge	(Micro) filtration	Solvent extraction	Phase separation	Chromatography	Ultra/dia-filtration	Drying
F	Y	✓	✓	✓	✓	✓	✓	NA	✓

Phospholipids case study

There are three potential market segments that differ based on purity levels; precision fermentation-made phospholipids can offer advantages in cost and safety

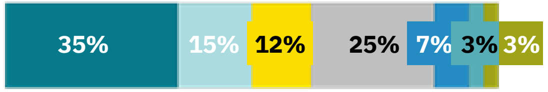
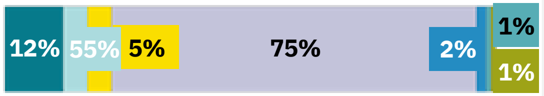
Requirements for phospholipids	Affordability	Safety	Nutritional value	Functionality	**Potential benefits compared to conventional**
Infant formula nutrition & functionality	High willingness to pay	Zero tolerance for pathogens[1], stricter than food for other[2]	Functional benefits for cognition and anti-stress	Limited digestibility for infants	✓ Possibly cheaper than conventional production ($99/kg vs $153/kg) ✓ Free of contaminants[1] from raw materials
Functional adult nutrition	Medium willingness to pay	Medium tolerance (zero for pathogens[1], limits for other[2])		Product usability and handiness	✓ Possibly cheaper than conventional production ($27/kg vs $127/kg) ✓ Free of contaminants[1] from raw materials
General food functionality enhancer & preservative	Low willingness to pay	Medium tolerance (zero for pathogens[1], limits for other[2])	None	Vibrant hues to support product appearances	✓ Possibly cheaper than conventional production ($27/kg vs $84/kg) ✓ Free of contaminants[1] from raw materials

Notes: (1) e.g., European Commission set MRLs (Maximum Residue Levels) for pesticide to 0.01mg/kg for general food and <0.01mg/kg for infant formula (2) e.g., pesticides, heavy metals (e.g., lead, cadmium), microbiological hazards, nitrates. Source: expert interviews, Green Queen, Arthur D. Little

Phospholipids case study

The estimated CoP of PF-made phospholipids are estimated at ~$27-99/kg at 200kl harvest volume, depending on purity level

Base case assumptions phospholipids

Unit cost driver	**Food-grade purity** (~95% ±10%)	**High purity** (>99%)	**Assumption basis**[1]
Production region	United States		*Arbitrary*
Host type	Filamentous Fungi		*Biofuel Research Journal 41(2024) 2040-2064*
Secretion type	Intracellular		*Biofuel Research Journal 41(2024) 2040-2064*
Culture volume @ harvest *(m^3)*	200		*GFI technical team*
Target yield on substrate *(g/g)*[2]	0.13		*Sci Rep 6, 36421 (2016)*
Substrate cost *($/kg)*	$0.60		*Industry interviews / triangulation*
Titre @ harvest *(g/l)*	40		*GFI technical team*
DSP configuration	1. Cell lysis 2. Centrifugation 3. Solvent Extraction 4. Phase Separation 5. Spray Drying	1. Cell lysis 2. Centrifugation 3. Solvent Extraction 4. Phase Separation 5. Chromatography 6. Spray Drying	*European Journal of Lipid Science and Technology 110(5):472 – 486;* *Food Hydrocolloids, Volume 111, 2021, 106357*
DSP yield	52%	42%	*Industry interviews / triangulation;* *GFI technical team*
Batch length *(days)*	4.7	4.6	
Batches (#/year)	78	79	
Output product *(kg powder/batch)*	4,159	3,327	
Base unit cost *($/kg)*	**$27**	**$99**	
Breakdown of unit costs	 35% 15% 12% 25% 7% 3% 3%	 12% 55% 5% 75% 2% 1% 1%	*Raw materials* *Labour* *Capex* *Consumables* *Other²* *Maintenance/ Insurance* *Utilities*

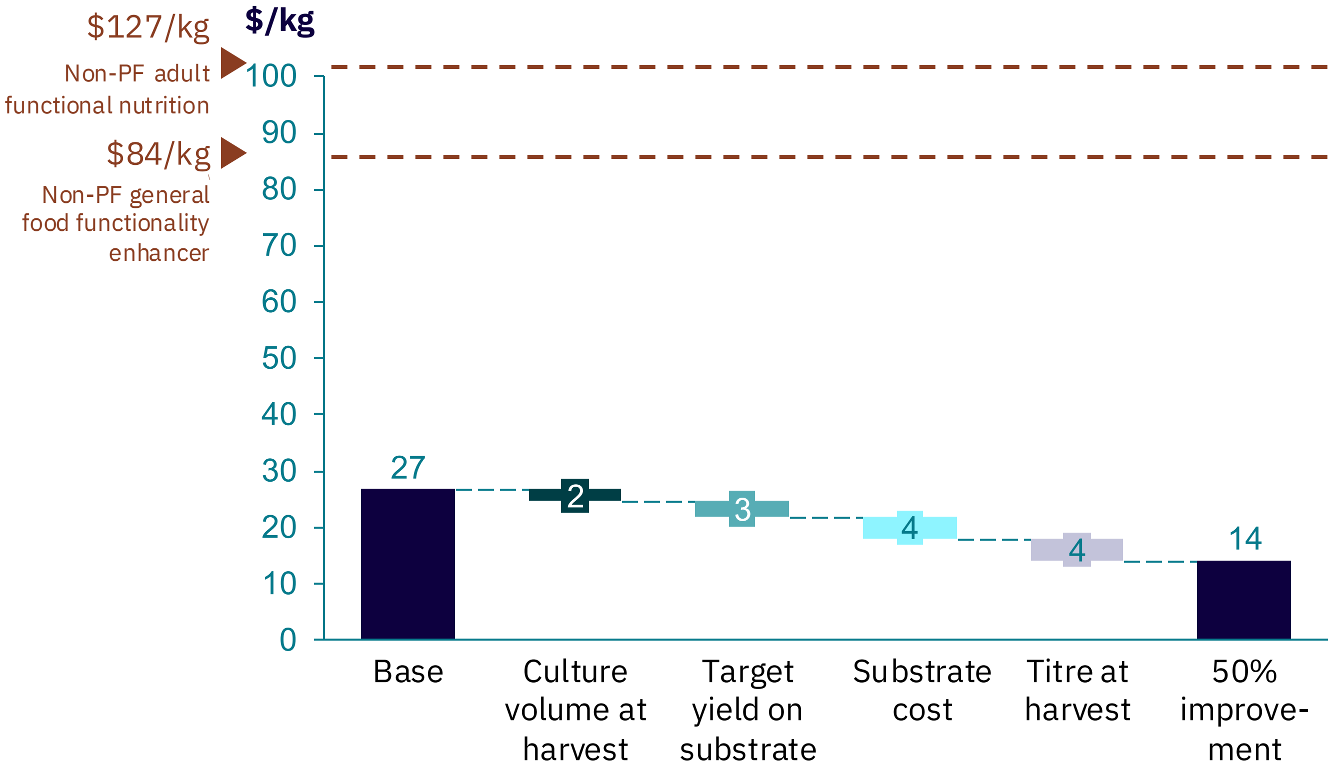
Sensitivity tested on upcoming slides

Note: Grams of target molecule (phospholipids in this case) per gram of non-water media additive (sugars, growth factors, buffers, etc.) Includes QC/QA/Laboratory and waste disposal. Source: Arthur D. Little

Phosphopholipids case study

For food-grade purity phospholipids, the unit cost declines from $27/kg to $14/kg with improvement in four key cost drivers

Unit cost sensitivities to key variables for food-grade purity phospholipids



50% improvement vs "base" assumptions

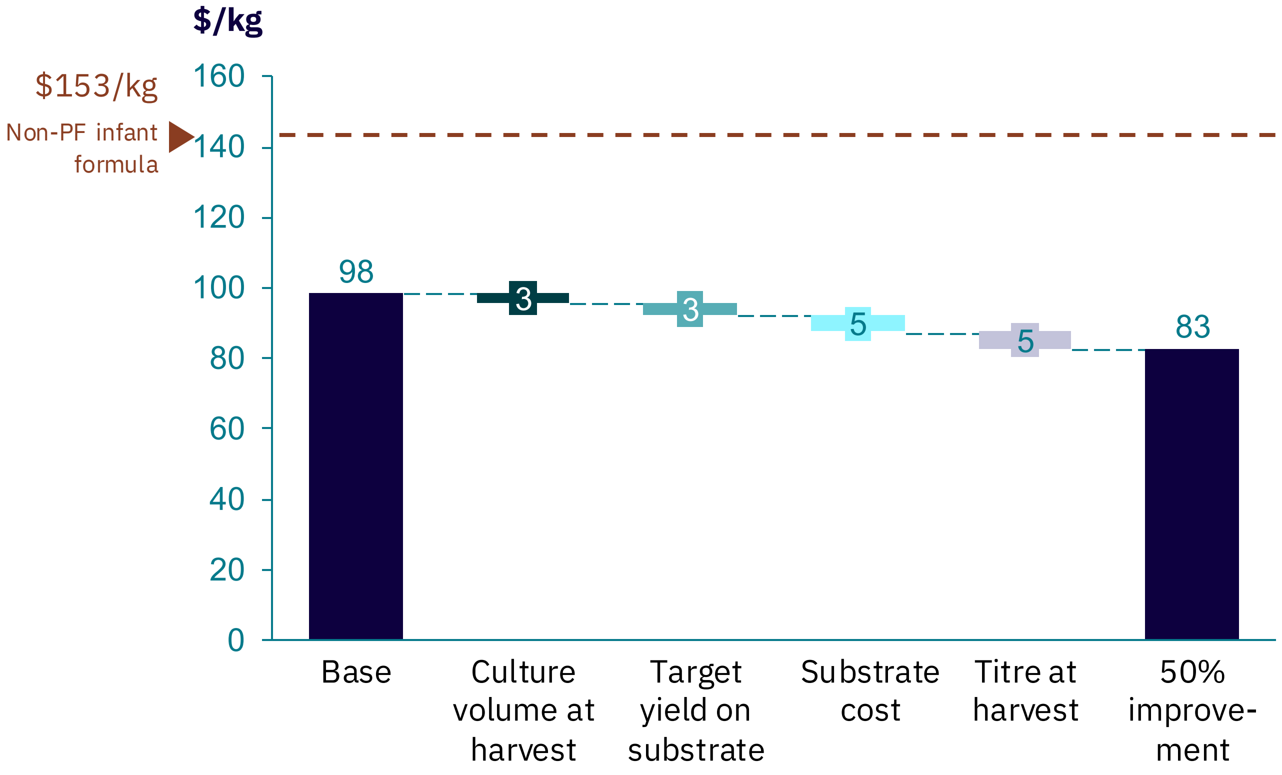
Improvement scenarios		
Variable	Base	50%
Target yield on substrate *(g/g)*[2]	0.13	0.19
Substrate cost *($/kg)*	$0.60 / kg	$0.30 / kg
Culture volume at harvest *(m³)*	200 m³	300 m³
Titre at harvest *(g/l)*	40 g/l Titre	60 g/l Titre
Cost	**$27**	**$14**

Source: Arthur D. Little

Phospholipids case study

For high purity phospholipids, the unit cost declines from $99/kg to $83/kg with improvement in four key cost drivers

Unit cost sensitivities to key variables for high purity phospholipids



50% improvement vs "base" assumptions

Improvement scenarios		
Variable	Base	50%
Target yield on substrate *(g/g)*[2]	0.13	0.19
Substrate cost *($/kg)*	$0.60 / kg	$0.30 / kg
Culture volume at harvest *(m^3)*	200 m^3	300 m^3
Titre at harvest *(g/l)*	40 g/l Titre	60 g/l Titre
Cost	**$99**	**$83**

Source: Arthur D. Little

Phosphopipids case study

On a cost-in-use basis, PF-made phospholipids may be even more competitive for all applications

The role of cost-in-use

Cost-in-use accounts for the **actual quantity needed to deliver equivalent functionality –** meaning that higher purity or more efficient ingredients can reduce required dosages, lower formulation or processing costs, and ultimately lead to a more competitive total cost.

		Application specs		Cost-in-use comparison			
Application	Method	Required purity (%)	Inclusion rate (%)	Purity (%)	Molecule amount (g/kg product)	Cost of molecule (USD/kg molecule)	Cost-in-use (USD/kg product)
Infant formula nutrition & functionality	**Conventional method**	**95-99%**	**0.02-0.11%**	99%	0.6	153	0.10
	Precision fermentation			**99%**	0.6 0%	98 -35%	0.06 -35%
Functional adult nutrition	**Conventional method**	**80-99%**	**0.1-9%**	90%	50	127	6
	Precision fermentation			**95%**	48 -5%	27 -79%	1 -80%
Functionality enhancer & preservative	**Conventional method**	**70-95%**	**~0.5%**	70%	7	84	0.6
	Precision fermentation			**95%**	5 -26%	27 -68%	0.1 -76%

Source: Arthur D. Little

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Conclusion

The findings here aim to support companies and academia in crafting viable pathways to market

Of the 67 molecules,

24%

show potentially favourable cost dynamics if produced via PF

Precision fermentation holds real commercial promise. Competing in low-margin industries such as the food sector is inherently challenging. A targeted go-to-market approach for PF production requires selecting molecules where there are competitive market entry price points and market sizes large enough to support sustained operations while platforms mature towards competing in large-scale, cost-sensitive commodity markets.

50% improvement in four key variables drives

~15-50%

production cost declines in two molecule case studies

Identifying key cost levers is essential. To drive meaningful cost reduction, R&D efforts should be focused on technical and process levers with the highest impact on cost reduction. For the two molecules analysed in depth, this analysis found that a 50% improvement across four key cost drivers (target yield on substrate, substrate costs, culture volume at harvest, and titre at harvest) could result in cost reductions of ~15-50%.

Robust market intelligence is foundational: The precision fermentation CoP model and market estimates presented here are directional tools. These can and should be strengthened by more real-world data on prices, market sizes, and production costs. Greater transparency can help accelerate sector-wide progress.

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Presence of existing players

Below are the companies we identified as active in the prioritised molecules

Group	Archetype	Molecule	Existing startups	Existing corporates
Protein	P2	**Chymosin**		DSM, Chr. Hansen (Novonesis)
Protein	P6	**Lactoferrin**	TurtleTree, Helaina, All G Foods, De Novo Food Labs	FrieslandCampina
Protein	P1	**Brazzein**	Novel Foods Group, Conagen/Sweegen, Levprot Biosciences, Oobli Foods	
Protein	P6	**Albumin (human and bovine)**		Lazuline Biotech
Protein	P5	**Elastin**	Geltor	
Protein	P1	**Myoglobin**	Paleo	
Protein	P2	**Thaumatin**	Conagen/Sweegen	
Protein	P1	**Leghemoglobin**	Impossible Foods	
Protein	P6	**α-lactalbumin**	21st.bio	
Fat & lipid	L7	**Phospholipids**	Nourish Ingredients	

Note: Companies with an existing presence refer to those that have either a commercial product on the market or clearly indicate (e.g. through their website or official communications) that they are actively developing one. Source: Arthur D. Little

Market size and prices for conventional and estimated PF molecules

Group	Molecule	Archetype	Market value (M USD)	Market size (MT)	Avg price (USD/kg)	PF average price	Market size source 1	Market size source 2	Market size source 3	Price data source
Protein	**Brazzein**	P1	400	1,455	275	28	Brazzein Market Size, Share, Trends, Industry Analysis & Forecast	Brazzein Market - Share, Growth & Industry Forecasts 2033		Alibaba
Protein	**Leghemoglobin**	P1	41	150	275	28	Heme Market Size, Analysis, Share | Global Report, 2032	(2) Heme Market Growth (2024-2032) | 109 Pages Report | LinkedIn		Volza
Protein	**Monellin**	P1	473	0	28,960,000	28	Monellin Market: Global Industry Analysis and Forecast (2023-2029)	Monellin Market Size, Share, Scope, Trends And Forecast 2030		Alibaba
Protein	**Myoglobin**	P1	99	528	187	28	Myoglobin Market Growth Trends, Global Analysis Report, 2024-2032	Myoglobin Market Size, Share & Trends Analysis Report 2030		Alibaba
Protein	**Casein**	P2	3,400	485,714	7	28	Casein and Caseinate Market Size and Share | By 2034	Casein & Casein Derivatives Market Size, Share, Growth-2032		SigmaAldrich
Protein	**Chymosin**	P2	4,600	44,878	103	28	Fermented Chymosin Market Size, Industry Share – 2032	Chymosin Market Size, Competitors, Trends & Forecast to 2030		Alibaba
Protein	**Collagen**	P2	5,100	680,000	8	28	Link	Link	Link	Alibaba
Protein	**Glycomacropeptide (GMP)**	P2	98	39,328	3	28	Global Glycomacropeptide (GMP) Supplements Market Size 2031 Surfing the Waves of Dynamics | LinkedIn	Global Glycomacropeptide (GMP) Supplements Market Impact of AI and Automation | LinkedIn		Volza
Protein	**Ovalbumin**	P2	26,050	2,112,741	12	24	Ovalbumin Powder Market Size, Trends & Forecast – 2032 | FMI	Ovalbumin Powder Market Size, Share, Growth, Industry Trend 2032		Volza, USTIC
Protein	**Thaumatin**	P2	61	436	140	28	Thaumatin Market: Size, Share, Growth Report, Analysis by 2023-2030	Thaumatin Market Size, Industry Report, Trends 2032		Alibaba
Protein	**α-lactalbumin (food-grade)**	P2	462	31,828	15	24	Global Market Study on Alpha Lactalbumin: Alpha-Lactalbumin to Witness a Potential Growth in the Sports Nutrition Industry	Alpha-lactalbumin Market Size, Outlook & Forecast 2033 | FMI		Alibaba
Protein	**β-lactoglobulin (food-grade)**	P2	12,350	1,122,727	11	28	Global Market Study on Alpha Lactalbumin: Alpha-Lactalbumin to Witness a Potential Growth in the Sports Nutrition Industry	Alpha-lactalbumin Market Size, Outlook & Forecast 2033 | FMI		Alibaba
Protein	**Avidin**	P3	220	1,119	197	105	Link	Link	Link	Alibaba
Protein	**Lysozyme**	P4	493	1,763	280	97	Global Lysozyme market size is USD 492.80 million in 2024.	Global Lysozyme Market Research Report 2024		Volza

Market size and prices for conventional and estimated PF molecules

Group	Molecule	Archetype	Market value (M USD)	Market size (MT)	Avg price (USD/kg)	PF average price	Market size source 1	Market size source 2	Market size source 3	Price data source
Protein	**Elastin**	P5	2,100	8,750	240	119	Elastin Market Size and Projections	Hydrolyzed Elastin Market Growth and Analysis 2032		Alibaba
Protein	**Fibronectin**	P5	125	410	305	119	Recombinant Human Fibronectin Market Research Report 2032			Alibaba
Protein	**Phosvitin**	P5	0	0	3,581,800	119				
Protein	**Tropoelastin**	P5	0	0	364,485,000	119				
Protein	**Vitellogenin**	P5	0	0	441	119				
Protein	**Albumin (Human and Bovine)**	P6	41	85	485	105	Link	Link	Link	Alibaba
Protein	**Conalbumin (Ovotransferrin)**	P6	363	0	789,700	105	Global Conalbumin Market Research Report 2024(Status and Outlook)	Conalbumin Market Size, Share, Trends, Growth, Forecast, 2032		Alibaba
Protein	**Immunoglobulins (IgG, IgA)**	P6	15,700	285,455	55	105	Immunoglobulin Market Size, Growth & Global Report 2032	Immunoglobulin Market Size To Reach USD 28.70 Billion By 2034		Alibaba
Protein	**Lactoferrin**	P6	635	1,588	400	105	Lactoferrin Market Size & Share Report, 2021-2028	Bovine Lactoferrin Market Size, Share, Analysis, Report, 2032		Alibaba
Protein	**Milk Fat Globule Membrane (MFGM) Proteins**	P6	96	23,337	4	105	MFGM Ingredients Market Size, Share, Trends & Growth 2032	Milk Fat Globule Membrane(MFGM) Market Size & Forecast		Alibaba
Protein	**Ovomucoid**	P6	0	0	966	105				Alibaba
Protein	**α-lactalbumin (high purity)**	P6	462	3,740	123	100	Global Market Study on Alpha Lactalbumin: Alpha-Lactalbumin to Witness a Potential Growth in the Sports Nutrition Industry	Alpha-lactalbumin Market Size, Outlook & Forecast 2033 | FMI		Alibaba
Protein	**β-lactoglobulin (high purity)**	P6	3,600	211,765	17	105	Link	Link	Link	Volza

Market size and prices for conventional and estimated PF molecules

Group	Molecule	Archetype	Market value (M USD)	Market size (MT)	Avg price (USD/kg)	PF average price	Market size source 1	Market size source 2	Market size source 3	Price data source
Lipid	**Lauric Acid**	L1	213	34,080	6	35	Link	Link	Link	Alibaba
Lipid	**Myristic and Palmitic Acids**	L1	915	57,178	16	35	Palmitic Acid Market Size, Share And Trends Report, 2030	Myristic Acid Market Size,Share & Growth Report 2032		Alibaba
Lipid	**Oleic Acid**	L1	476	136,029	4	35	Global Oleic Acid Market Poised for Significant Growth: USD	Global Oleic Acid Market Size, Share & Forecast 2030	Oleic Acid Market Size, Share & Trends Analysis Report 2030	Volza
Lipid	**Stearic Acid**	L1	31,820	15,545,361	2	35	Stearic Acid Market Regional Analysis Size, Suppliers to 2031	Stearic Acid Market Size Projected to Surge USD 70.17		Volza
Lipid	**Triacylglycerols**	L2	861	51,376	17	42	Medium-Chain Triglycerides Market Size, Sales, Share & Trends	Medium-chain Triglycerides Market Size | Forecast Report, 2032		Alibaba
Lipid	**Lecithin**	L3	570	51,826	11	42	Global Lecithin Market Size & Share Report, 2022 - 2030	Lecithin Market Size, CAGR, Outlook & Forecast Report 2032		Volza
Lipid	**Ceramides**	L4	375	12,507	30	31	Global Market Study on Ceramides: Rising Significance of Natural Personal Care Ingredients to Drive Demand	Ceramide Market Size to Surpass USD 747.62 Million by 2034	Ceramide Market Size, Share & Global Forecast Report - 2032	Alibaba
Lipid	**Sphingolipids**	L4	601	8,590	70	31	Sphingolipids Market Size, Share, Outlook & Trends - 2032	Sphingolipids Market Share, Analysis | Global Report, 2032	Sphingolipids Market is anticipated to reach US$ 991.8 Million by end of 2032, at a CAGR of 5.1% - PharmiWeb.com	Volza
Lipid	**Omega-6 Fatty Acids**	L5	1,214	136,404	9	97	Link	Link	Link	Volza
Lipid	**Monoolein**	L6	218	14,032	16	97	Link	Link	Link	Alibaba
Lipid	**Monostearin**	L6	1,630	32,600	50	97	Link	Link	Link	Volza
Lipid	**Phosphatidylcholine**	L7	1,327	8,294	160	119	Link	Link	Link	Volza
Lipid	**Phosphatidylethanolamine**	L7	0	0	144,497	119	Link	Link	Link	Alibaba
Lipid	**Phospholipids**	L7	3,440	22,557	153	99	Phospholipids Market Share, Growth & Industry Report, 2033	Phospholipids Market Size, Share, Industry Growth 2032		Volza
Lipid	**EPA/DHA (Omega 3)**	L8	2,620	65,500	40	105	Link	Link	Link	Volza

Market size and prices for conventional and estimated PF molecules

Group	Molecule	Archetype	Market value (M USD)	Market size (MT)	Avg price (USD/kg)	Market size source 1	Market size source 2	Market size source 3	Price data source
Small Molecule	**Benzaldehyde**	S1	294	80,757	4	Link	Link	Link	Alibaba
Small Molecule	**Cinnamaldehyde**	S1	6,000	404,995	15	Link	Link	Link	Volza
Small Molecule	**Citronellal**	S1	130	4,337	30	Link	Link	Link	Volza
Small Molecule	**Ethyl Acetate**	S1	5,480	1,178,495	5	Link	Link	Link	Volza
Small Molecule	**Ethyl Butyrate**	S1	2,820	97,241	29	Link	Link	Link	Volza
Small Molecule	**Eugenol**	S1	235	7,820	30	Link	Link	Link	Volza
Small Molecule	**Geraniol**	S1	13,588	1,181,548	12	Geraniol Market: Industry Analysis and Forecast	Geraniol Market Growth and Forecast to 2030		Alibaba
Small Molecule	**Isoamyl Acetate**	S1	390	53,067	17	Link	Link	Link	Volza
Small Molecule	**Limonene**	S1	335	52,375	6	Limonene Market Size, Share And Growth Report, 2030	Continue Reading...		Volza
Small Molecule	**Linalool**	S1	463	53,759	9	Linalool Market Share to Worth $696.2 Billion by 2030	Linalool Market Size, Share, Growth | CAGR of 4.3%		Alibaba
Small Molecule	**Menthone**	S1	1,915	122,560	16	D L Menthone Glycerol Ketal Market Research Report 2032	Menthone Market Size & Future Growth 2032		Alibaba
Small Molecule	**Methyl Salicylate**	S1	1,540	280,000	6	Link	Link	Link	Volza
Small Molecule	**α-Ionene**	S1	233	38,861	6	Ionone Market: Global Industry Analysis And Forecast	Alpha-Ionone Market Size, Share, Growth and Industry Trends | LinkedIn		Volza
Small Molecule	**2-Phenylethanol**	S2	492	14,252	35	Link	Link	Link	Alibaba
Small Molecule	**Ethyl Maltol**	S2	24,000	2,181,818	11	Link	Link	Link	Volza
Small Molecule	**Glutamate**	S2	10,161	6,842,155	1	Link	Link	Link	Volza
Small Molecule	**Menthol**	S3	755	23,231	33	Global L-Menthol Market Report, History and Forecast 2023-2029	[2024-2030] Menthol Market Size, Company | LinkedIn		Volza

Market size and prices for conventional and estimated PF molecules

Group	Molecule	Archetype	Market value (M USD)	Market size (MT)	Avg price (USD/kg)	Market size source 1	Market size source 2	Market size source 3	Price data source
Small Molecule	**Vanillin**	S4	1,040	34,667	30	Vanillin Market Size, Industry Share & Trends, 2033	Vanillin Market Size, Share & Growth Analysis Report, 2030		Volza
Small Molecule	**Capsaicin**	S5	257	1,285	200	Capsaicin Market Size & Share, Growth Analysis - 2036	Capsaicin Market Size, Competitors & Forecast to 2030		Volza
Small Molecule	**Carotenoids**	S5	2,500	72,954	34	Carotenoids Market Size, Share, Trends and Industry Analysis	Carotenoids Market Size, Share, Analysis & Forecast 2031		Alibaba
Small Molecule	**Carminic Acid**	S6	41	135	305	Carmine Market Size, Trends Report 2030 | The Brainy Insights	Carminic Acid Market Research Report 2032		Alibaba
Small Molecule	**Inosinate and Guanylate**	S6	800	32,000	25	Link	Link	Link	Alibaba
Small Molecule	**Steviol Glycosides**	S6	5,000	63,617	79	Steviol Glycoside Market Demand, Trends, Industry Size | The Brainy Insights	Steviol Glycosides Market: Global Analysis Report by 2033		Alibaba
Small Molecule	**Anthocyanin**	S7	356	3,629	98	Anthocyanin Market Size	Anthocyanin Market - Manufacturers & Size		Volza