WHITE PAPER | SPECIALTY BIOCATALYSIS FOR OMEGA-3 LIPIDS

BioSCat A 15G

Enzymatic Processing of Fish Oil and Omega-3 Lipids

A CALB-based biocatalyst platform for esterification, re-esterification, transesterification and structured lipid manufacture

EPA/DHA-RICH FEEDSTOCK	MILD BIOCATALYTIC CONVERSION	HIGH-VALUE OMEGA-3 LIPIDS

PURPOSE OF THIS WHITE PAPER

To describe how BioSCat A 15G can be applied in fish-oil and omega-3 lipid processing, with emphasis on scientifically established CALB reaction routes. The document intentionally excludes graphs and does not assign fixed dosage or operating conditions; those should be validated against the actual feedstock, target lipid form and BioSCat A 15G product specification.

Prepared by SD Biocare

Biocatalysis Solutions for Functional Lipids

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Executive Summary

Fish oil is one of the most technically demanding lipid feedstocks used for nutritional products. Its value is driven by the long-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), yet those same highly unsaturated molecules are vulnerable to oxidation and can be sensitive to harsh processing. Conventional chemical conversions can be effective, but high temperature, strong catalysts or aggressive downstream neutralization can increase process stress and purification burden.

BioSCat A 15G is SD Biocare's CALB-based biocatalyst platform for controlled lipid conversion. Candida antarctica lipase B (CALB) is widely used in industrial and research biocatalysis because it can catalyze esterification and transesterification in low-water or non-aqueous systems, including reactions involving EPA- and DHA-rich substrates. In fish-oil processing, this enables practical routes for converting free fatty acid concentrates to glycerides, manufacturing omega-3 ethyl esters, re-esterifying omega-3 concentrates, and preparing structured triacylglycerols under comparatively mild conditions.

The commercial value of the enzyme route is not simply "more omega-3." The strongest proposition is process control: targeted bond formation or exchange, lower thermal exposure, the possibility of solvent-free operation, reduced inorganic catalyst residues, and—when the biocatalyst is immobilized—potential recovery and reuse. The actual yield, reaction time, regioselectivity and EPA/DHA profile depend on feedstock composition, water activity, alcohol or glycerol ratio, temperature, mass transfer and reaction endpoint.

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Key positioning

BioSCat A 15G should be evaluated as a precision processing catalyst for omega-3 lipid conversion. It is especially relevant after upstream concentration has produced an EPA/DHA-rich fatty-acid or ester stream that must be converted into the desired commercial lipid form.

1. Why Fish Oil Processing Benefits from Biocatalysis

Omega-3 oils are chemically different from ordinary commodity fats. EPA contains five double bonds and DHA contains six, creating high nutritional value but also a strong need to limit oxidation, overheating and unnecessary residence time. A suitable lipase process can operate at temperatures substantially below those used in many conventional chemical transformations and can often be designed around low-water, solvent-free or reduced-solvent conditions.

- Milder conversion conditions can help reduce avoidable thermal stress on highly unsaturated lipids.
- Enzyme catalysis can reduce reliance on strong mineral acids or bases for esterification/transesterification.
- High reaction specificity can simplify the reaction mixture and support cleaner downstream processing.
- Immobilized biocatalysts can be separated from the oil phase more readily than soluble enzymes and may be suitable for repeated cycles, subject to validated activity retention.
- The same catalyst platform can support multiple commercial lipid forms depending on substrate and reaction partner.

2. BioSCat A 15G: Role in Omega-3 Lipid Conversion

BioSCat A 15G is positioned for CALB-type lipid transformations in which ester bonds are formed, exchanged or reorganized. The enzyme is therefore most useful when the processor already knows the desired endpoint—for example, an omega-3 ethyl ester, a re-esterified triacylglycerol, or a structured glyceride—and wants a controlled route to that endpoint.

Reaction route	Typical feed	Value for fish-oil processing
Direct esterification	EPA/DHA-rich free fatty acids + glycerol	Re-esterified mono-, di- and triacylglycerols; reaction can be driven toward TAG by controlling water removal and stoichiometry.
Ethyl esterification	EPA/DHA-rich free fatty acids + ethanol	Omega-3 ethyl esters; literature demonstrates CALB-catalyzed DHA and n-3 PUFA esterification, including solvent-free approaches.
Transesterification / interesterification	Fish-oil glycerides or omega-3 esters + suitable acyl/alcohol partner	Exchange of acyl groups or alcohol moieties to create a target lipid structure.
Structured lipid synthesis	Purified or concentrated EPA/DHA streams + glycerol backbone	Tailored glyceride products with controlled fatty-acid incorporation.
Re-esterification after concentration	Omega-3 concentrate in FFA or EE form	Conversion to glyceride-rich formats intended for nutrition or formulation applications.

3. Application Route A — Re-Esterified Omega-3 Triglycerides

One of the most commercially relevant uses of CALB is the synthesis of glycerides from EPA/DHA-rich free fatty acids. The scientific literature has demonstrated high conversion of polyunsaturated fatty acids from fish and microalgae oils into triacylglycerols using immobilized C. antarctica lipase. This route is important when an upstream concentration or purification step generates a free-fatty-acid concentrate that must be converted back to a glyceride form.

The reaction is equilibrium-limited, so water management is central. Water is formed as glycerol and fatty acids esterify; if it accumulates, the reverse hydrolysis reaction becomes increasingly important. Practical process designs therefore use controlled dehydration, vacuum, dry gas, molecular sieves or other validated methods to lower water activity without exposing the oil to excessive oxygen or heat.

- Start with a low-oxidation, low-moisture EPA/DHA concentrate.
- Control the glycerol-to-fatty-acid molar ratio to favor the desired glyceride distribution.
- Remove reaction water progressively to drive esterification forward.
- Monitor FFA/acid value and glyceride profile, not only overall conversion.
- Protect the batch with nitrogen or another suitable inert-gas strategy where appropriate.

4. Application Route B — Omega-3 Ethyl Ester Manufacture

CALB can catalyze esterification of omega-3 free fatty acids with ethanol. Published work has demonstrated ethyl esterification of DHA in an organic-solvent-free system using immobilized C. antarctica lipase, as well as efficient solvent-free esterification of several n-3 polyunsaturated fatty acids. This makes BioSCat A 15G relevant where the target commercial intermediate or finished lipid is an EPA/DHA ethyl ester.

Ethanol can both participate in the reaction and influence enzyme activity. Excess alcohol is not always beneficial, and water generated by esterification can limit equilibrium conversion. A staged alcohol strategy, controlled dehydration or other process-intensification approach may therefore outperform a single large ethanol charge. Literature results should be treated as a starting point rather than a BioSCat A 15G process specification.

Important distinction

Ethyl esterification is a conversion step. It should not automatically be described as an EPA/DHA concentration step. Enrichment depends on the composition of the starting material and the selectivity of the complete process, including any preceding or subsequent separation.

5. Application Route C — Transesterification and Structured Lipids

Lipase-catalyzed transesterification can exchange acyl groups between lipid molecules or convert one ester form to another. In omega-3 processing, this creates opportunities for structured triglycerides, tailored glyceride distributions and specialty lipid ingredients. Early work with immobilized Candida antarctica lipase demonstrated synthesis of highly enriched EPA or DHA triglycerides by direct esterification and interesterification routes. The practical implication is that CALB is not limited to hydrolysis: it is a strong bond-forming catalyst for high-value PUFA chemistry.

For structured lipid development, the target product must be defined analytically before process optimization begins. Total EPA+DHA is not enough. The processor may need to control TAG/DAG/MAG distribution, residual ethyl esters, free fatty acids, glycerol, positional distribution, sensory properties and oxidative markers.

Critical variable	Why it matters	Process response
Water activity	Too much water favors hydrolysis; too little can reduce catalytic flexibility in some systems.	Dry feedstocks; validated dehydration; monitor moisture and acid value.
Temperature	Affects reaction rate, enzyme stability and oxidation risk.	Use the lowest practical temperature that provides acceptable kinetics; validate against BioSCat specification.
Alcohol concentration	High ethanol can alter enzyme performance and phase behavior.	Consider staged addition and endpoint-driven dosing.

Glycerol ratio	Controls equilibrium and glyceride distribution.	Optimize molar ratio for TAG target, not simply maximum conversion.
Mass transfer	Viscous oil phases and glycerol can create transfer limitations.	Adequate agitation without excessive air entrainment.
Oxygen exposure	PUFAs oxidize readily.	Closed reactor, inert-gas handling, suitable antioxidants where formulation permits.

6. Recommended Fish-Oil Processing Workflow

A robust BioSCat A 15G process should be built around the chemistry of the incoming oil rather than around a fixed "standard dose." The following development workflow is recommended for pilot evaluation.

Stage	Recommended development action
1. Feedstock characterization	Measure EPA/DHA profile, FFA/acid value, moisture, peroxide value, p-anisidine value, glyceride/ethyl-ester profile, color, metals and key contaminants relevant to the intended market.
2. Define the target lipid form	Specify whether the product should be ethyl ester, FFA, TAG-rich re-esterified oil, structured lipid or another defined glyceride composition.
3. Prepare the substrate	Dry/dehydrate as needed, minimize oxygen exposure, and precondition glycerol, ethanol or other co-substrate.
4. Charge BioSCat A 15G	Select an initial enzyme loading based on laboratory screening and the current product specification; avoid transferring a dosage directly from another CALB preparation.
5. Control reaction conditions	Optimize temperature, mixing, molar ratio, water removal and residence time. Use nitrogen blanketing or equivalent oxidation control where appropriate.
6. Track conversion	Use acid value and compositional analysis at defined intervals. For re-esterification, monitor TAG/DAG/MAG. For ethyl esterification, monitor EE formation and residual FFA.
7. Stop and separate	At the validated endpoint, separate the immobilized catalyst and proceed to polishing, deodorization or other downstream steps as required.
8. Verify product quality	Confirm EPA/DHA content, oxidation markers, residual reactants, glyceride/ester profile, sensory quality and regulatory specifications.

7. Oxidation Control Is Part of the Enzyme Process

The success of an omega-3 conversion cannot be judged by conversion yield alone. A high-yield process that significantly increases peroxide value, secondary oxidation products or off-odors is not commercially successful. Enzymatic processing can reduce thermal severity, but the reactor still requires deliberate oxidation control.

- Use fresh, well-refined feedstock with controlled initial peroxide and p-anisidine values.
- Limit oxygen ingress during charging, sampling, agitation and product transfer.
- Avoid unnecessary heating and extended hold times after the reaction endpoint.
- Use suitable food-grade antioxidants where compatible with the intended product and regulatory framework.
- Track TOTOX or equivalent oxidation indicators through the full process, not only in the final batch.

8. Quality Control and Release Testing

For fish-oil processors, enzyme conversion must integrate with the existing quality system. The analytical plan should link reaction performance with final oil quality and customer specification.

Test	Why it matters
Fatty-acid profile by GC	Confirms EPA, DHA and total omega-3 composition.
Acid value / free fatty acids	Tracks esterification progress and residual FFA.
TAG / DAG / MAG / EE profile	Defines the actual lipid form and conversion endpoint.
Moisture / water activity	Supports process control and enzyme-performance interpretation.
Peroxide value	Measures primary oxidation.
p-Anisidine value	Measures secondary oxidation products.
TOTOX or combined oxidation index	Provides a broader view of oxidative condition.
Residual ethanol / glycerol, where relevant	Confirms downstream removal and product compliance.
Color / odor / sensory assessment	Important for nutritional oils and consumer acceptance.
Contaminants and heavy metals	Verify against destination-market and customer requirements.

9. Why BioSCat A 15G for Fish-Oil Processing

BioSCat A 15G gives fish-oil manufacturers a biocatalytic option for conversion steps that are traditionally performed using chemical catalysts or higher-severity processing. Its strongest value proposition is the combination of CALB chemistry with an application-development approach focused on the real feedstock and desired commercial lipid form.

- Suitable platform for esterification and transesterification involving EPA/DHA-rich substrates.
- Supports development of re-esterified triglyceride and structured lipid formats.
- Can be evaluated in low-water and solvent-free process concepts where technically appropriate.
- Potential for cleaner catalyst separation and reuse when applied as an immobilized biocatalyst, subject to cycle testing.
- Enables process optimization around mild temperature, reduced thermal load and targeted lipid chemistry.
- Backed by SD Biocare application support for laboratory screening, reaction-condition optimization and scale-up design.

Application-development principle

BioSCat A 15G should be qualified against the customer's actual fish-oil stream. Feedstock origin, EPA/DHA level, FFA/EE/TAG distribution, moisture, oxidation status and target product form can materially change the optimum enzyme loading and reaction conditions.

10. BioSCat Line of Lipases: Oils & Fats Processing and API Manufacturing

Beyond BioSCat A 15G, SD Biocare offers a broader BioSCat line of lipase platforms for targeted ester-bond chemistry. The portfolio allows processors to match enzyme selectivity to the substrate and desired reaction route across oils &

fats processing and API/intermediate manufacturing. Selection should be based on substrate structure, positional or stereochemical selectivity, water activity, reaction medium, temperature, downstream separation and the required product specification.

BioSCat lipase platform	Oils & fats processing	API manufacturing / biocatalysis
BioSCat A 15G — CALB-based lipase	Fish-oil re-esterification; EPA/DHA ethyl esters; esterification and transesterification; structured lipids and specialty glycerides.	Stereoselective esterification/transesterification; kinetic resolution; preparation of chiral ester intermediates and other high-value building blocks, subject to substrate screening.
BioSCat — CALA	Specialty lipid modification, hydrolysis and esterification where activity toward bulky or long-chain substrates is advantageous.	Selective transformations of sterically demanding acids/alcohols and specialty intermediates where CALA-type substrate preference is useful.
BioSCat — TL Lipase	Regioselective interesterification; TAG/DAG restructuring; modification of vegetable oils, specialty fats and functional lipid systems.	Regioselective ester hydrolysis or transesterification where positional selectivity can simplify intermediate synthesis and downstream purification.
BioSCat — Rhizopus Lipase	Selective hydrolysis/interesterification; structured-lipid development; specialty oils and omega-3 process development requiring a complementary lipase selectivity.	Regioselective ester conversions and specialty intermediate synthesis where a Rhizopus-derived lipase provides the preferred substrate response.

Portfolio use principle: The same lipase should not be assumed to be optimal for every oils & fats or API reaction. SD Biocare can screen BioSCat platforms against the customer's substrate and target conversion to establish the preferred enzyme, loading, reaction conditions and reuse strategy. Product-specific activity, immobilization format, carrier and grade should be confirmed against current SD Biocare technical documentation.

11. Pilot Trial Framework

A practical pilot program can be completed as a small factorial screen rather than a single-point trial. The objective is to identify a processing window that balances conversion, oxidation control, catalyst productivity and downstream simplicity.

Factor	Suggested comparison	Primary decision metric
Baseline	Current chemical or existing enzyme process	Benchmark conversion, yield, oxidation and cycle time.
BioSCat loading	Low / medium / high within supplier-guided range	Establish productivity and diminishing returns.
Temperature	Two or three mild operating points within validated product limits	Balance kinetics versus oxidation and catalyst stability.
Water management	No active removal vs controlled removal strategy	Determine equilibrium limitation and effect on endpoint.
Co-substrate ratio	Glycerol or ethanol at selected molar ratios	Optimize target lipid form and residual reactants.
Reuse cycle	Fresh catalyst plus repeated batches where applicable	Measure retained activity and product consistency.

12. Scientific Basis

Published literature supports the use of immobilized Candida antarctica lipase in omega-3 chemistry. Studies have demonstrated synthesis of EPA- and DHA-rich triglycerides, esterification of fish-oil PUFA concentrates with glycerol, and solvent-free ethyl esterification of DHA and other n-3 polyunsaturated fatty acids. More recent work continues to investigate CALB-containing immobilized systems for fish-oil transformation and omega-3 processing. These studies establish the reaction platform; they do not replace product-specific BioSCat A 15G validation.

Selected Scientific References

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Technical Note

This white paper is intended for technical and commercial evaluation. Reaction conditions cited from scientific literature illustrate CALB capability and are not a guaranteed BioSCat A 15G specification. Final dosage, temperature, residence time, catalyst-reuse strategy and product claims should be established through application trials using the customer's feedstock and the current SD Biocare product documentation.

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