REDUCING RELIANCE ON WILD FISH AND OTHER NATURAL RESOURCES FOR SALMON FEEDS

SOURCING NUTRIENTS FROM UNDERUTILIZED RAW MATERIAL CATEGORIES

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INTRODUCTION

CURRENT NEEDS IN SALMON NUTRITION

Industry continues to rely on fish meal and fish oil as key ingredients

Marine ingredient pricing is volatile, but generally increasing—this continues to incentivize the search for alternatives

Considerations related to the use of alternative ingredients

- **Effects on performance and product quality** (e.g., survival and growth rates, nutritional value of farmed salmon)
- **Environmental implications** (e.g., conversion of natural habitat to agricultural production, diet digestibility and nutrient retention rates)

By controlling costs where we can, we can make room for other improvements and offer innovation to support salmon aquaculture

COMMON INGREDIENTS

PROS & CONS OF TRADITIONAL SALMONID FEED INGREDIENTS

MARINE PROTEINS & LIPIDS

Nutrient-dense, highly digestible

Amino acid and fatty acid profiles match unique demands of carnivorous fish

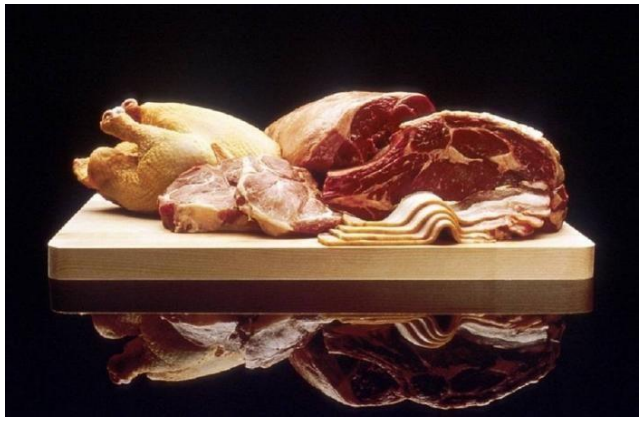
High cost, concerns related to sustainability and wild fish inputs

PLANT PROTEINS & LIPIDS

Lower nutrient density and digestibility, antinutritional factors

Essential amino and fatty acids are limiting or completely absent

Concerns related to agricultural practices, genetic engineering, processing costs, etc.



ANIMAL PROTEINS & LIPIDS

Nutrient-dense, highly digestible

Competitive pricing

Regulatory limitations, concerns related to product safety, market access and consumer acceptability

NOVEL INGREDIENTS

PROS & CONS OF EMERGING SALMONID FEED INGREDIENTS

‘NEW’ MARINE PROTEINS & LIPIDS

Nutrient-dense, high digestibility and palatability

Concerns related to cost, scalability, potential for contamination (filter-feeders)

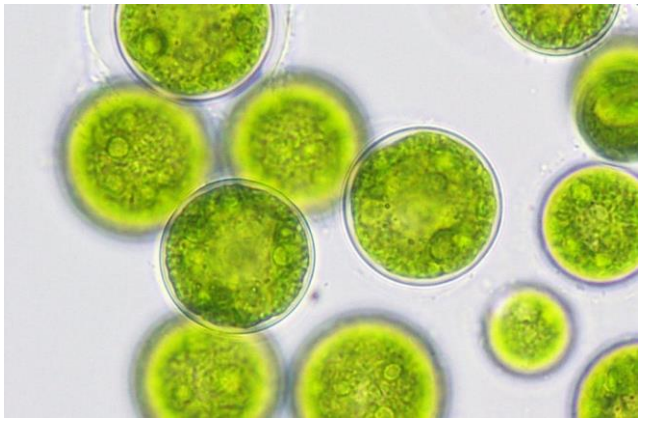
Defer or redirect concerns, but do not resolve issues related to sustainability and wild fish inputs

INSECT PROTEINS & LIPIDS

Lower nutrient density and digestibility, composition varies with feedstocks used, but largely mirrors terrestrial ingredients

Concerns related to cost, scalability, siting of insect propagation facilities

Regulatory limitations



ALGAL PROTEINS & LIPIDS

Nutrient density varies among algal species

Limited protein digestibility, unless processed extensively

Concerns related to cost, scalability, effect on product quality (can impart a ‘fishy’ taste)

ATTRIBUTES TO CONSIDER

IMAGINING THE IDEAL ALTERNATIVE INGREDIENT

Composition & practical feeding value
Protein content and quality
Carbohydrate content and type
Digestibility/availability of all nutrients
Presence of antinutritional factors and/or pigments

Economic & environmental costs
Production volumes and availability
Cost-effectiveness
Environmental impacts of production and sustainability

Influence on product quality
Nutritional value, appearance, and taste of farmed fish
Contaminant levels and safety

Market considerations
Public perception, traceability, other end users/demand

THERE ARE MANY, MANY INGREDIENTS THAT CAN SATISFY THE BIOLOGICAL NEEDS OF SALMON

THE GREATEST LIMITING FACTORS ARE COST, PRODUCTION VOLUMES SCALABILITY, ETC.

EMERGING INGREDIENTS SHOULD BE FOSTERED TO OVERCOME LOGISTICAL CONSTRAINTS, BUT

DELIVERING BETTER NUTRITION NOW REQUIRES PRAGMATISM

AND A FOCUS ON PRACTICALITIES

OPTIMAL NUTRITION

GROWTH ISN'T THE ONLY THING THAT MATTERS

THERE ARE FEW ASPECTS OF FISH PEFORMANCE THAT AREN'T DIRECTLY OR INDIRECTLY INFLUENCED BY DIET

WITH EXPERTISE IN FISH NUTRITION, HEALTH, AND PHYSIOLOGY, STIM IS WELL-POSITIONED TO ASSESS INGREDIENT SUITABILITY IN THE BROADER CONTEXT OF OPTIMAL PERFORMANCE

THE LAST THING A FISH WILL DO IS GROW

ALL OTHER DEMANDS MUST BE SATISFIED FIRST

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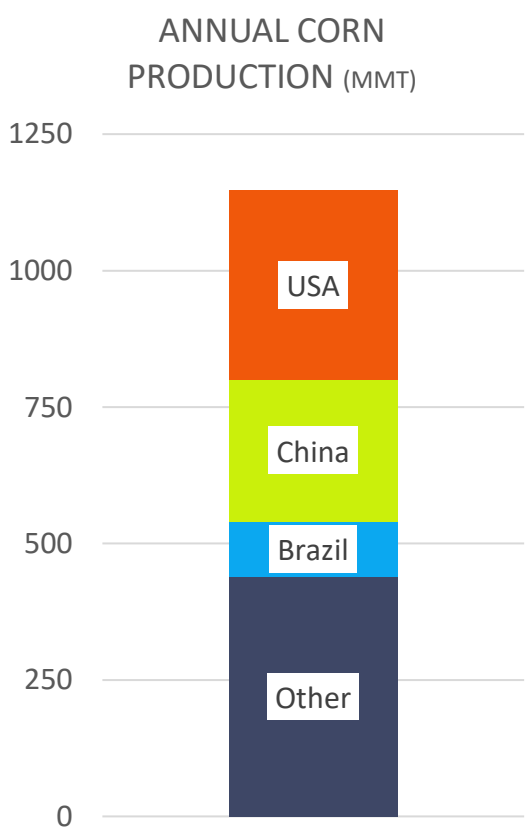
SOURCES: TOCHER 2003, LI ET AL. 2009

CORN AS AN ALTERNATIVE PROTEIN SOURCE

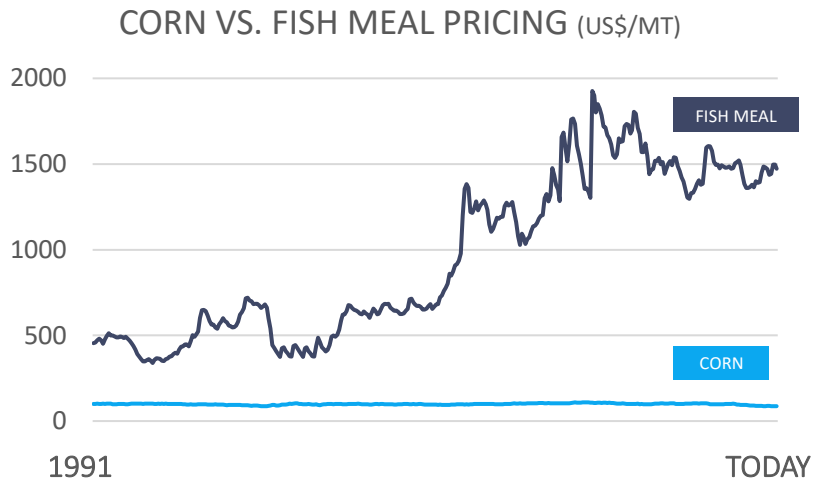
STRATEGIES TO IMPROVE NUTRITIONAL VALUE & COST-EFFECTIVENESS

CORN (MAIZE)

CHALLENGES & OPPORTUNITIES



Nutrient (% DM)	Corn	Fish Meal
Protein	8.8	65.4
Lysine	0.3	5.5
Methionine	0.2	2.1
Tryptophan	0.1	0.8
Threonine	0.3	3.1
Isoleucine	0.3	3.3
Leucine	1.1	5.4
Phenylalanine	0.4	2.9
Valine	0.4	3.8
Histidine	0.3	1.7
Arginine	0.4	4.0
Starch	61.6	<1.0
Fiber	10.0	1.0
Ash	1.2	14.3
Lipid	3.8	7.6



DESPITE LOW PRICING AND WIDESPREAD AVAILABILITY, CORN IS NOT A COMMON INGREDIENT IN SALMONID FEEDS BECAUSE OF ITS LOW PROTEIN CONTENT, HIGH STARCH CONTENT, AND UNBALANCED AMINO ACID PROFILE

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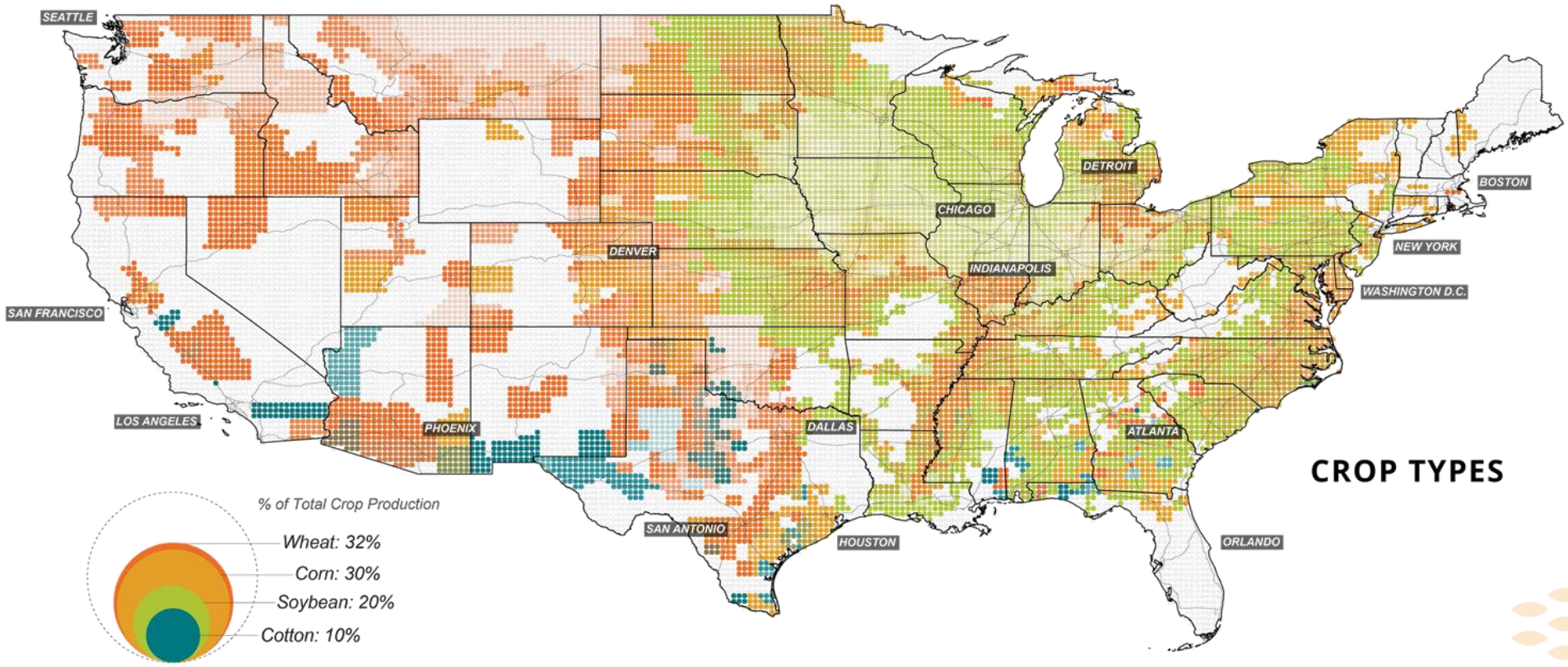
SOURCES: NRC 2011, VISUALCAPITALIST.COM 2015, LOY AND LUNDY 2019, FAOSTAT 2021, INDEXMUNDI.COM 2021

CORN (MAIZE)

CHALLENGES & OPPORTUNITIES



CORN IS ONE OF THE MOST WIDELY CULTIVATED CROPS IN THE MIDWESTERN USA

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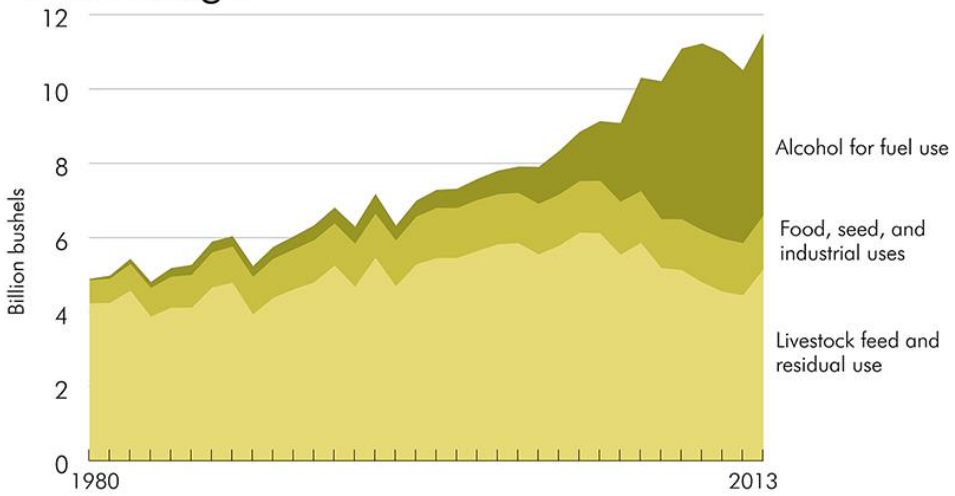
SOURCE: VISUALCAPITALIST.COM 2020

CORN (MAIZE)

CHALLENGES & OPPORTUNITIES

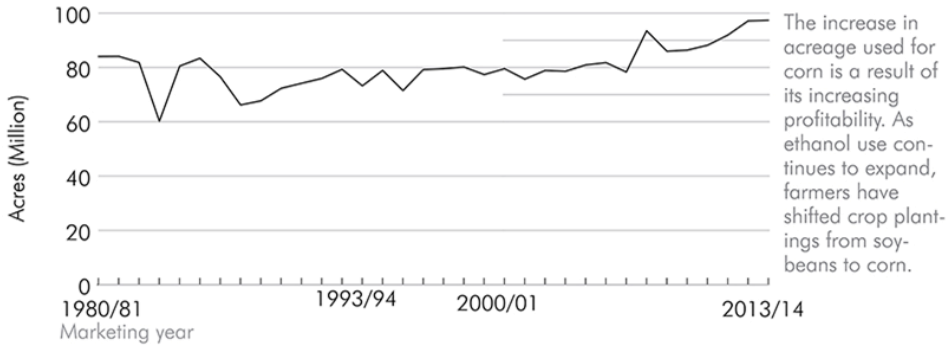
Corn usage



CORN PRODUCTION IS INCREASING, BUT THE USA AGRICULTURAL FOOTPRINT IS NOT EXPANDING

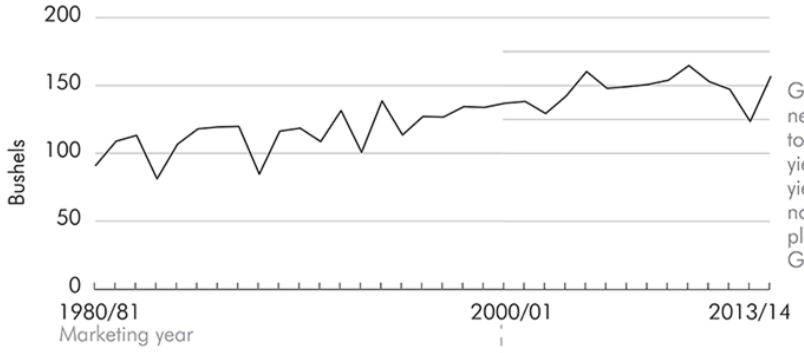
INCREASING ANNUAL PRODUCTIVITY IS DRIVEN BY IMPROVEMENTS IN YIELD AND CONVERSION OF OTHER CROPLANDS TO CORN PRODUCTION

US planted acres



The increase in acreage used for corn is a result of its increasing profitability. As ethanol use continues to expand, farmers have shifted crop plantings from soybeans to corn.

Corn yield per acre



Genetic engineering is touted to increase crop yields. However, yield data does not mirror the implementation rate GE corn.

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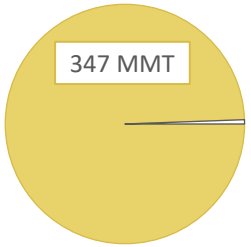
SOURCE: VISUALCAPITALIST.COM 2015

CORN (MAIZE)

CHALLENGES & OPPORTUNITIES

USA CORN PRODUCTION



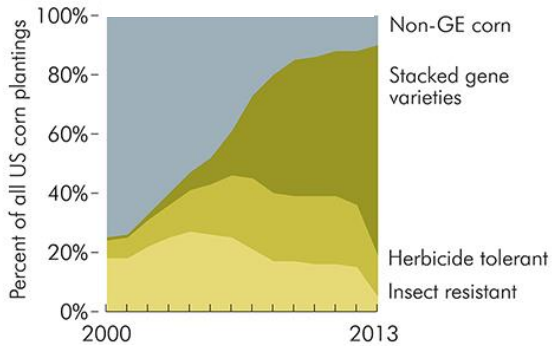
White corn is a small fraction of USA annual production, but its share is growing and already exceeds 2 MMT per year

YELLOW CORN IS THE MOST WIDELY CULTIVATED TYPE OF CORN, BUT LOW-CAROTENOID, WHITE VARIETIES ARE ALSO PRODUCED

THE MAJORITY OF CORN PRODUCED IN THE USA IS GENETICALLY MODIFIED, BUT CONVENTIONAL LINES ARE STILL IN PRODUCTION

Genetic engineering

In 2013, genetically engineered corn accounted for 90% of the planted crop showing a steep increase from just 25% in 2000. The majority of the current crop is known as stacked gene, meaning that it is both insect resistant and herbicide tolerant.



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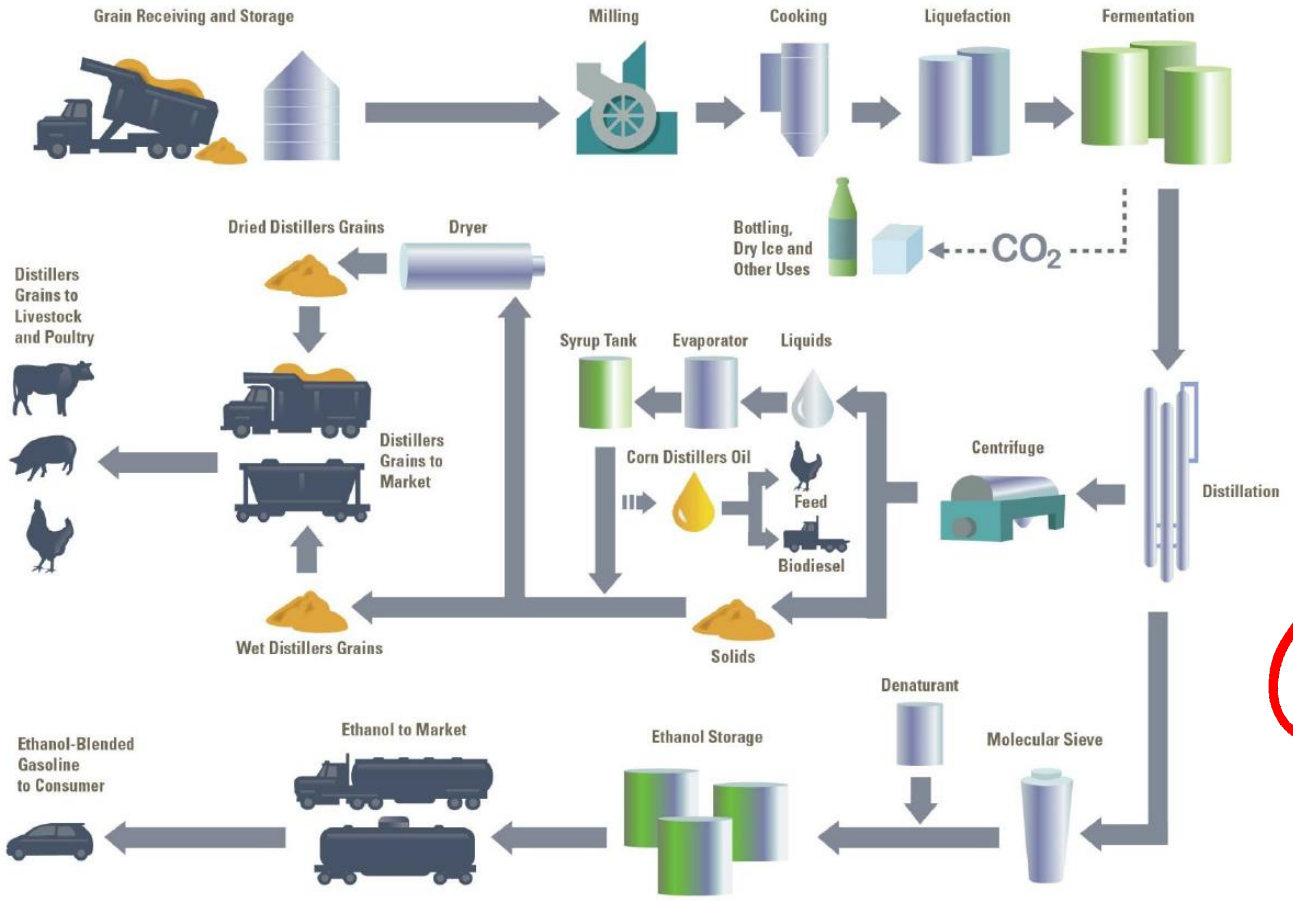
SOURCES: VISUALCAPITALIST.COM 2015, AgMRC 2018, BESWA ET AL. 2020

CORN-ETHANOL COPRODUCTS

FERMENTATION CONCENTRATES PROTEIN, REDUCES ANTINUTRIENTS



FARMING FOR FEED & FUEL

Fermentation of corn produces three primary classes of (co)products

Ethanol →	BIOFUELS
Carbon dioxide →	INDUSTRIAL USES
Residual yeast, corn oil and proteins →	ANIMAL FEEDS

CAN BE MODIFIED TO INCREASE VALUE FOR AQUATIC LIVESTOCK

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SOURCE: RENEWABLE FUELS ASSOCIATION 2011

GREEN PLAINS LLC

MAKER OF MSC™ AND OTHER FERMENTED CORN DERIVATIVES

12 Biorefineries
Strategically throughout the United States

10 Million
Tons of corn processed annually

Over 1 Billion Gallons
Our annual production capacity of low-carbon biofuels

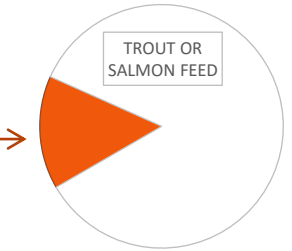
Over 700
Dedicated employees

Nutrient (% DM)	Corn	MSC™ 50
Protein	8.8	49.0
Lysine	0.3	2.1
Methionine	0.2	1.1
Tryptophan	0.1	0.5
Threonine	0.3	2.1
Isoleucine	0.3	2.1
Leucine	1.1	5.9
Phenylalanine	0.4	2.6
Valine	0.4	2.7
Histidine	0.3	1.4
Arginine	0.4	2.5
Starch	61.6	4.4
Fiber	10.0	16
Ash	1.2	4.8
Lipid	3.8	2.0

GREEN PLAINS LLC IS ONE OF THE LARGEST BIOFUELS PLATFORMS IN THE WORLD

RECOGNIZING THE POTENTIAL OF THEIR PROCESS TO PRODUCE HIGH QUALITY FEEDSTUFFS, THEY ARE INCREASINGLY FOCUSED ON IMPROVING THE QUALITY OF CORN-DERIVED PROTEINS FOR THE AQUACULTURE INDUSTRY

PROPRIETARY TECHNOLOGY IMPROVES UPON FERMENTATION TO FURTHER REFINE RESIDUAL CORN AND YEAST PROTEIN FOR AQUAFEED



Results to-date indicate MSC 50 can be incorporated at 15% of the diet, replacing costly fish meal and plant protein concentrates

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SOURCE: GPREINC.COM 2021, FLUID QUIP TECHNOLOGIES 2021

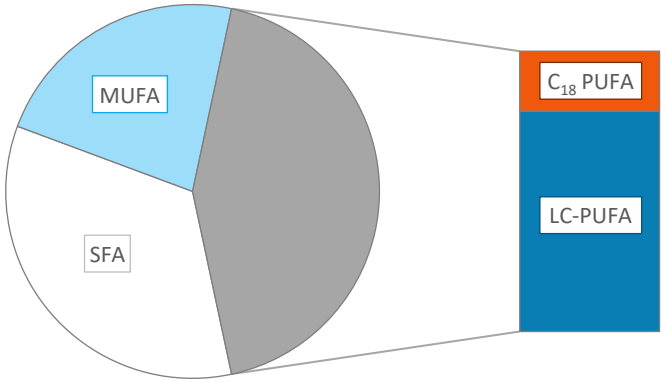
SUNFLOWER AS AN ALTERNATIVE LIPID SOURCE

STRATEGIES TO REDUCE FISH OIL USE WHILE MAINTAINING PRODUCT VALUE

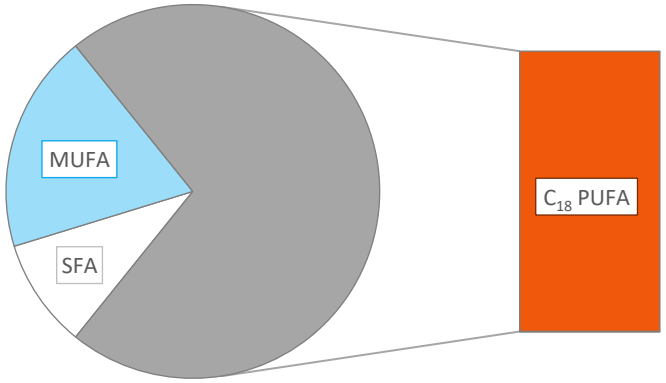
FISH OIL ALTERNATIVES

LIPIDS VARY IN THEIR FATTY ACID SIGNATURE AND NUTRITIONAL VALUE

FISH OIL



FLAXSEED$_{(LINSEED)}$ OIL

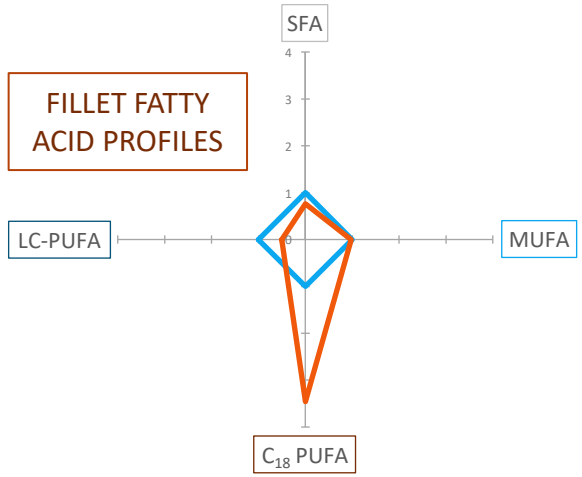


SALMONIDS GENERALLY ACCEPT A WIDE RANGE OF LIPID SOURCES

SO LONG AS ESSENTIAL FATTY ACID REQUIREMENTS ARE MET, GROWTH PERFORMANCE IS TYPICALLY MAINTAINED

HOWEVER, CHANGES IN DIETARY COMPOSITION ARE GENERALLY REFLECTED IN THE FILLETS, WHEREBY REDUCED DIETARY FISH OIL TRANSLATES INTO THE LOSS OF BENEFICIAL OMEGA-3 CONTENT

FILLET FATTY ACID PROFILES



DIETARY FATTY ACID PROFILES ARE GENERALLY REFLECTED IN THE EDIBLE TISSUES

LESS FISH OIL IN THE FEED USUALLY MEANS LESS NUTRITIONAL VALUE FOR THE CONSUMER

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SOURCE: TRUSHENSKI AND BOESENBERG 2009

FEEDING C_{18} PUFA vs. SFA & MUFA

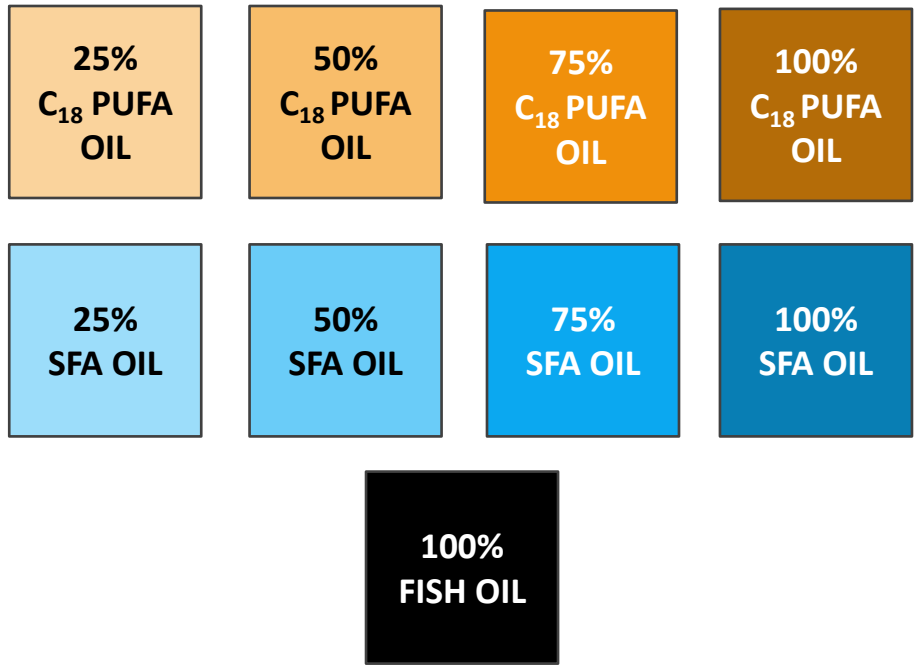
DISRUPTING THE 'FISH ARE WHAT THEY EAT' PARADIGM

THE SPARING EFFECT OF SFA & MUFA

Previous research has revealed counter-intuitive effects of diets rich in saturated (SFA) and monounsaturated fatty acids (MUFA)

Unlike other fatty acids, SFA are not proportionately reflected in the tissues

Fish were fed diets containing fish oil, or graded levels of standard C_{18} PUFA-rich oil or hydrogenated SFA-rich oil



DOI: 10.1080/15222055.2012.720650

FEEDING C_{18} PUFA vs. SFA & MUFA

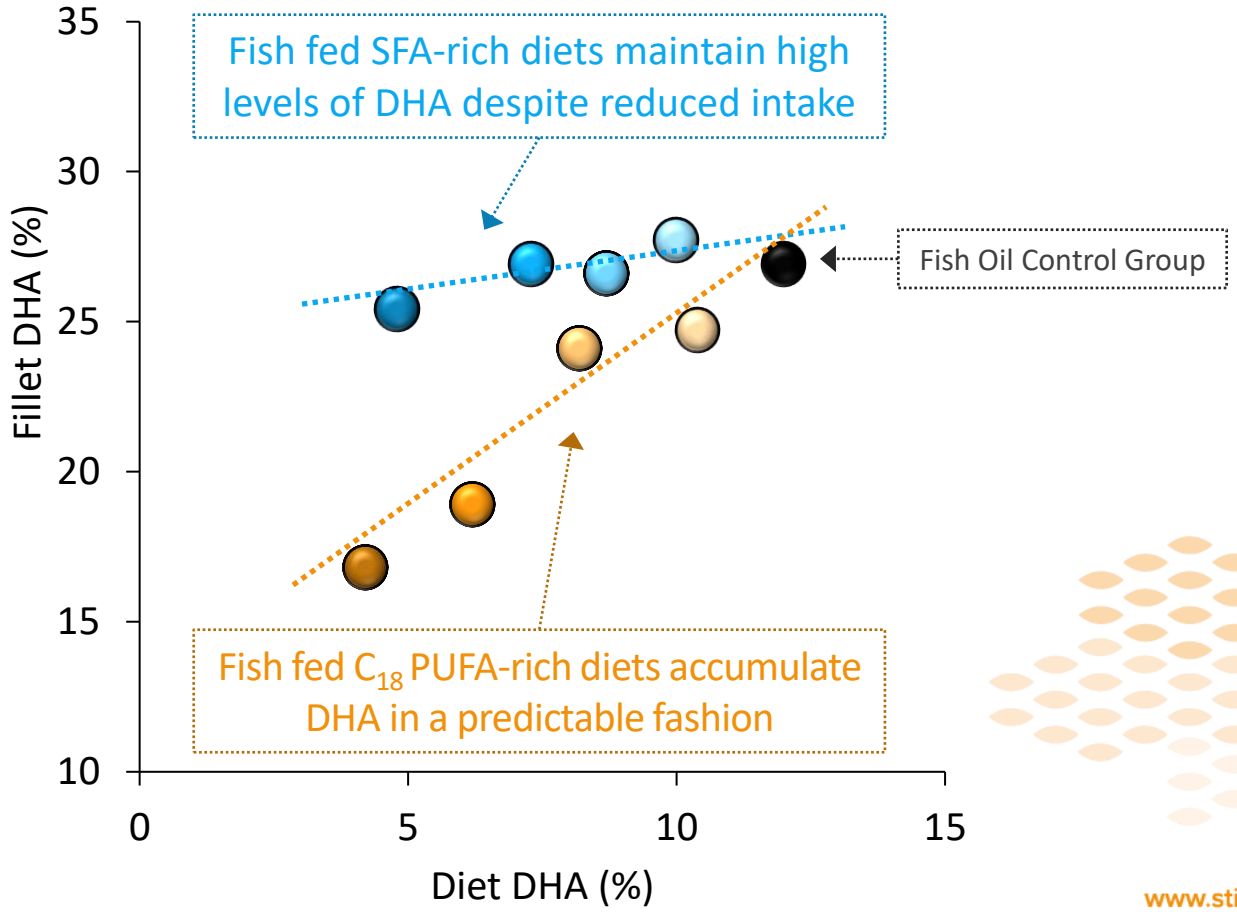
DISRUPTING THE 'FISH ARE WHAT THEY EAT' PARADIGM

THE SPARING EFFECT OF SFA & MUFA

Growth is often suppressed among fish fed high levels of C_{18} PUFA-rich diets but not SFA or MUFA-rich diets

High dietary levels of SFA and MUFA have a disproportionately small effect on tissue composition and facilitate greater fish oil sparing

This "omega-3 sparing effect" has now been observed in many species, including salmonids



DOI: 10.1080/15222055.2012.713897
DOI: 10.1080/15222055.2011.623947
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DOI: 10.1080/15222055.2012.720650
DOI: 10.1080/15222055.2013.811134
DOI: 10.1016/j.aquaculture.2015.05.041
DOI: 10.2527/jas2015-9199
DOI: 10.1111/anu.12502
DOI: 10.1007/s11745-016-4136-y

FEEDING C_{18} PUFA vs. SFA & MUFA

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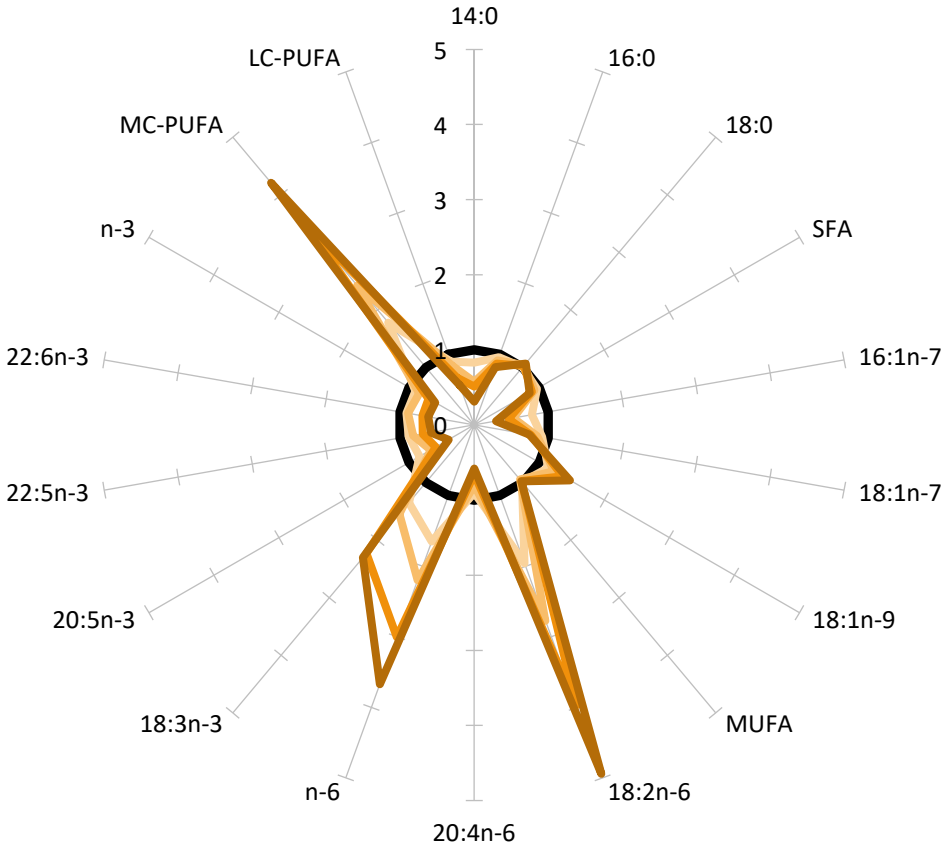
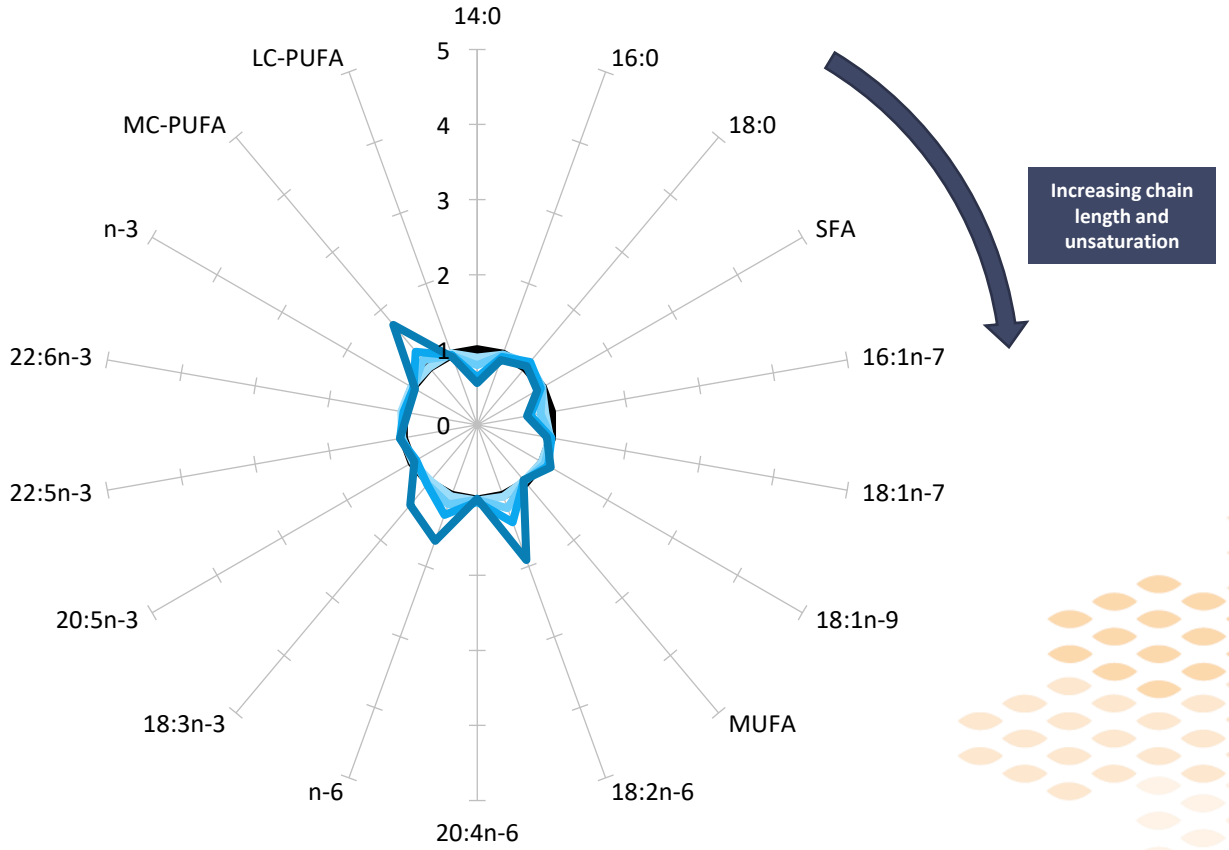


Dramatic fillet profile distortion among fish fed C_{18} PUFA-rich diets



Relatively consistent fillet fatty acid profiles among fish fed SFA-rich diets

FEEDING C_{18} PUFA vs. SFA & MUFA

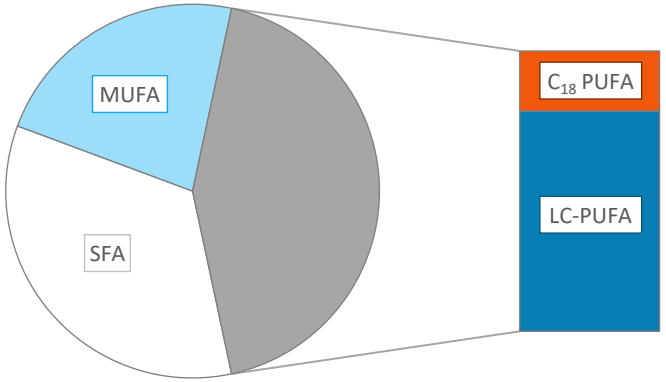
DISRUPTING THE 'FISH ARE WHAT THEY EAT' PARADIGM

NUMEROUS STUDIES, INCLUDING LONG-TERM AND FARM-SCALE TRIALS DEMONSTRATE THE VALUE OF SFA- AND MUFA-RICH LIPIDS IN ATLANTIC SALMON AND RAINBOW TROUT FEEDS

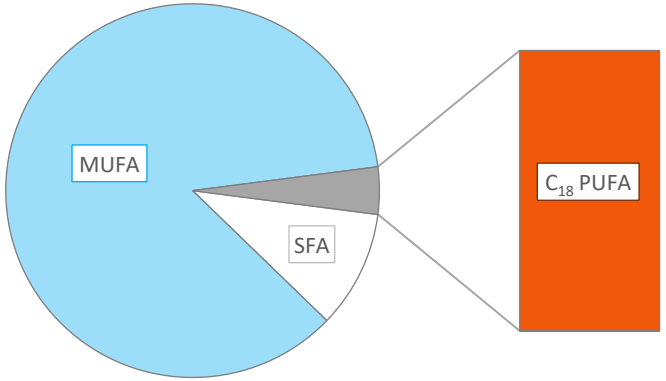
SUNFLOWER

CHALLENGES & OPPORTUNITIES

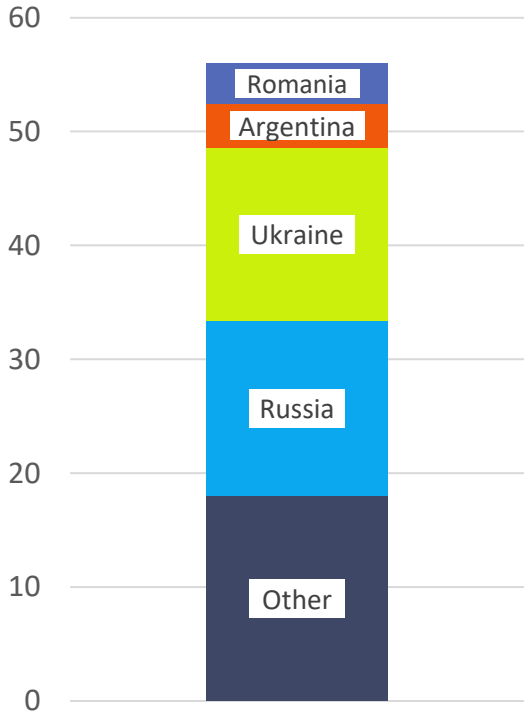
FISH OIL



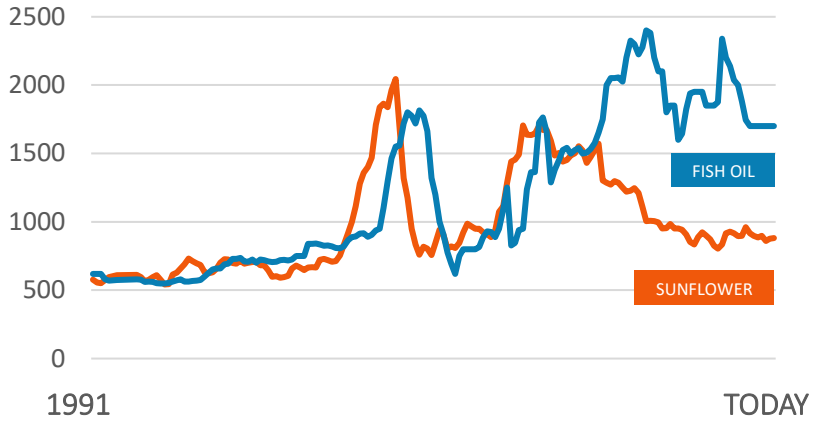
SUNFLOWER OIL



ANNUAL SUNFLOWER PRODUCTION (MMT)



SUNFLOWER VS. FISH OIL PRICING (US$/MT)



SUNFLOWER OIL PRICING IS COMPETITIVE WITH OTHER ALTERNATIVE LIPIDS

PROPORTIONS OF SFA AND MUFA TO C_{18} PUFA SUGGEST SUNFLOWER OIL WOULD SUPPORT SIGNIFICANT OMEGA-3 SPARING

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SOURCE: FAOSTAT 2021, INDEXMUNDI.COM 2021

CONCLUSIONS

NEXT STEPS TO ADDRESS NEEDS IN SALMON NUTRITION

The search for new feed inputs for aquaculture continues…and likely always will

Polarfeed remains committed to its philosophy of listening to the fish, delivering what they need to not just survive but thrive, and emphasizing practicality as we diversify our portfolio of ingredients

MSC-50 and sunflower oil are very promising resources, but our plans for innovation do not begin and end with these ingredients

Polarfeed has applied for research concessions to evaluate MSC-50 and sunflower oil at commercial scale in partnership with Norwegian salmon farmers

We have planned our work and now intend to work our plan. We will be assessing feed performance comprehensively, leveraging STIM's strengths in fish health and environmental services to look at the 'big picture'

We anticipate MSC-50 and sunflower oil-based feeds will be successful, and are prepared to manage the project adaptively with our partners to ensure that they are successful

Stay tuned for more information—anticipated project start date is in 2022!