Optimizing Diets for Rainbow Trout

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https://www.fws.gov/mountain-prairie/fisheries/ftc.php

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U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Agricultural Research Service
Trout-Grains Project
USDA
Hagerman, Idaho

From Horse Heads to Pellets

Rainbow trout nutrition has come a long way

NCTC Archives/Museum

NCTC Archives/Museum

Early 1900's:

natural prey items.

1920's and 1930's:

wet feeds were made based on what was available in close proximity to the hatcheries.

1940's:

plant meals were used such as wheat middlings, cottonseed meal and soybean meal.

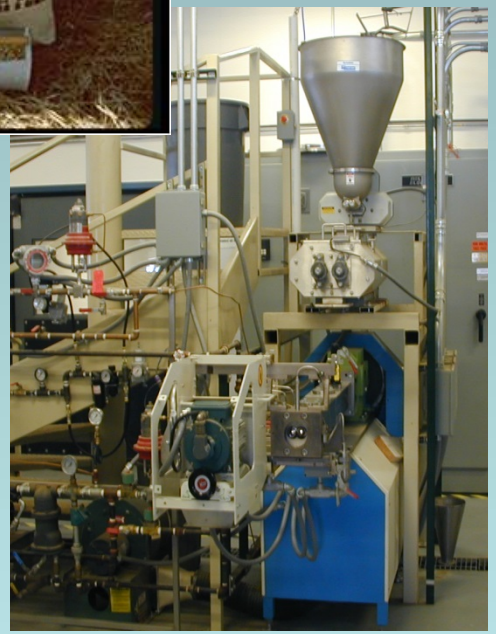
From Horse Heads to Pellets

Rainbow trout nutrition has come a long way

1950's:
the Oregon Moist Pellet was developed; made at low temperature with a pasta maker.

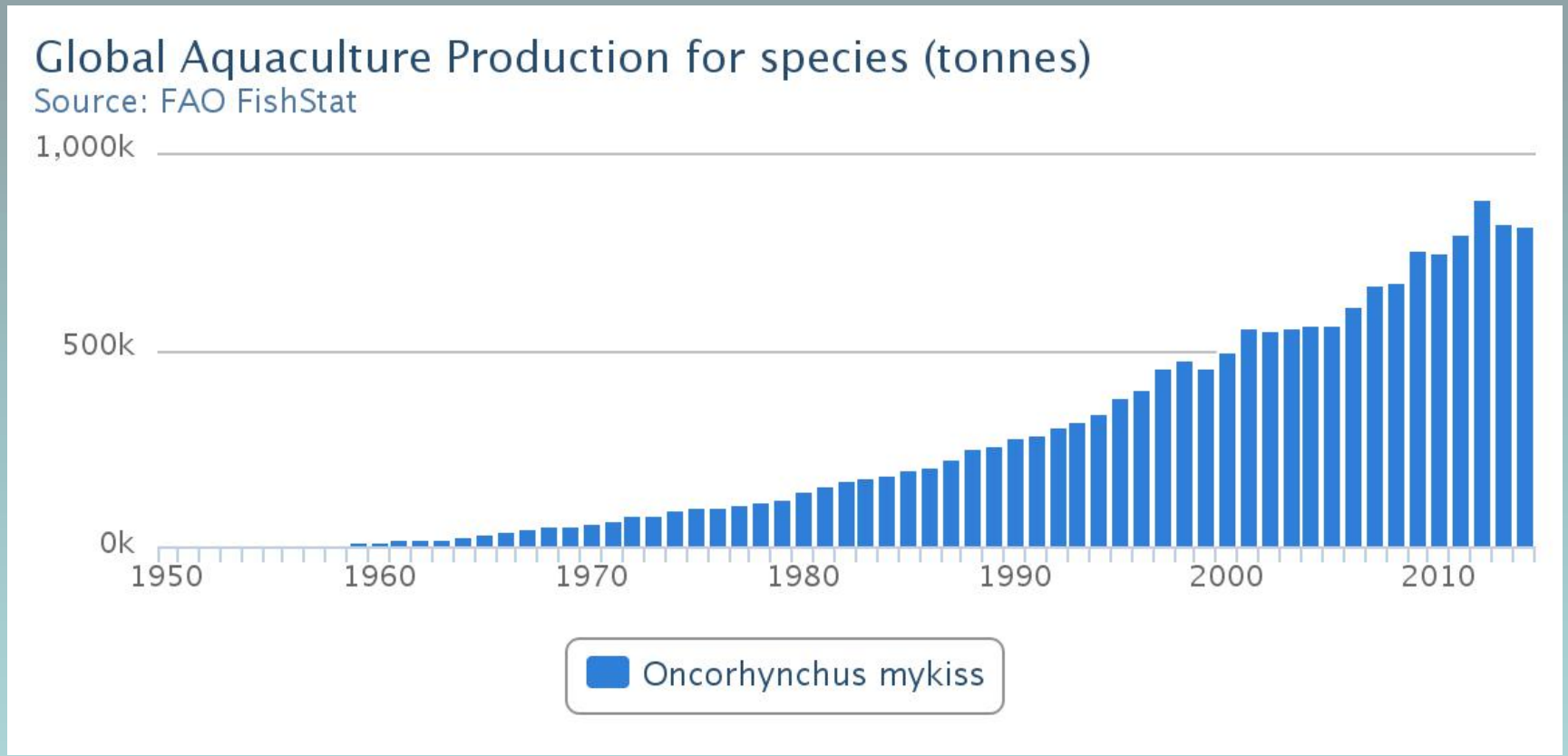
1960's:
the Abernathy Dry Diet was developed, a compressed pellet.

1970's to 1980's:
extrusion became the primary method of fish feed manufacture.



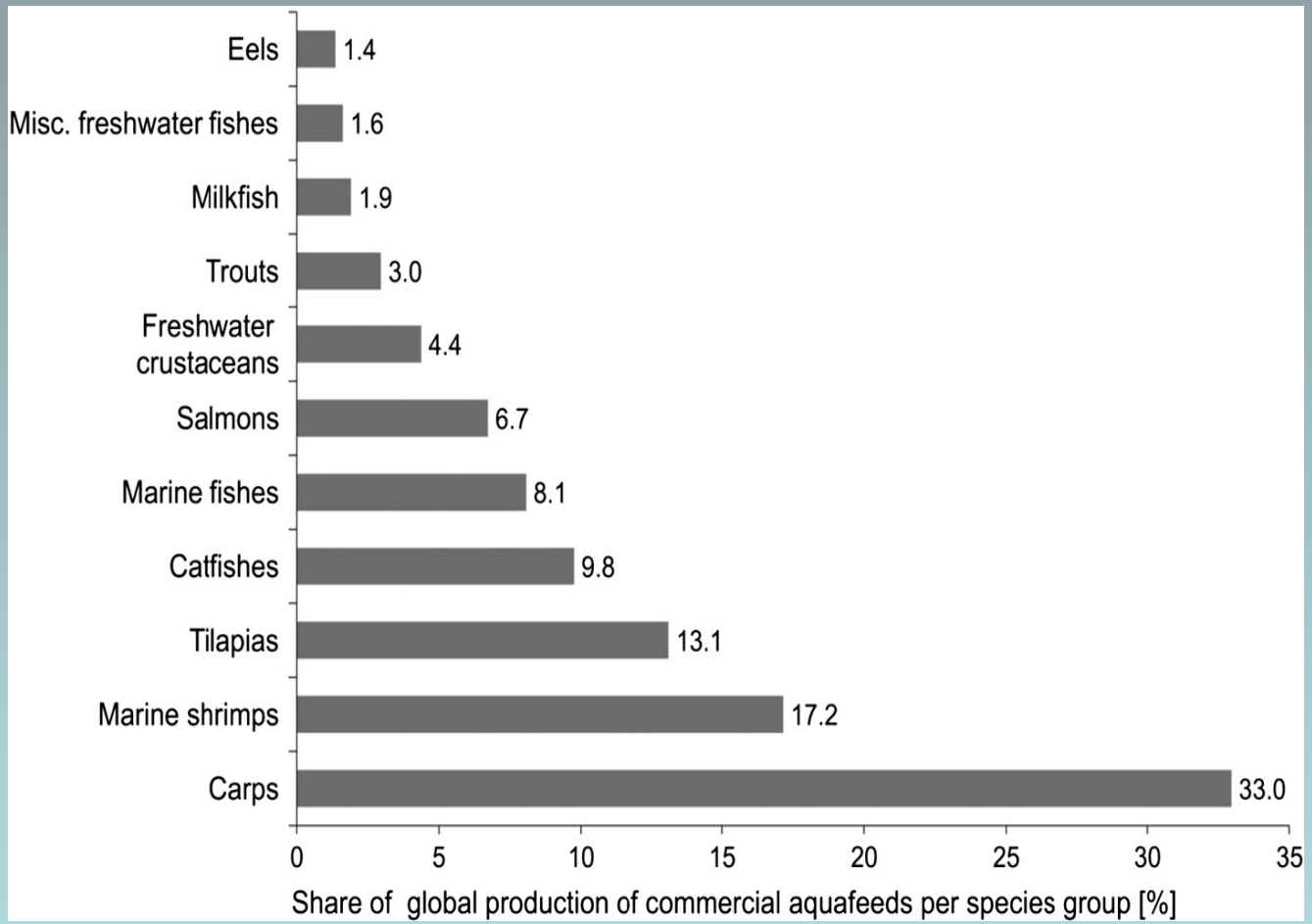
1980s to 2000's
nutrient dense diets
decreasing protein levels increased energy

Rainbow Trout's Global Aquaculture Production



•FAO 2005-2016.
Cultured Aquatic Species Information Programme. Oncorhynchus mykiss.
Text by Cowx, I. G. In: *FAO Fisheries and Aquaculture Department*
[online]. Rome. Updated 15 June 2005. [Cited 18 October 2016].

Rainbow Trout's Share Of Global Feed Production



•Share of global production of commercial aquaculture feeds of 29.7 million tonnes by major species grouping for the year 2008 (Pahlow et al. 2015 based on Tacon et al., 2011 and Ramakrishna et al., 2013).

What have you done for me lately?

- Reducing Fishmeal (and oil)
- Ingredient Diversity
- Ideal amino acid
  - AA supplementation
  - Taurine
- Defining micronutrient needs
  - Mineral supplementation
  - Functional supplements

Reducing dependence on Marine Harvested Products

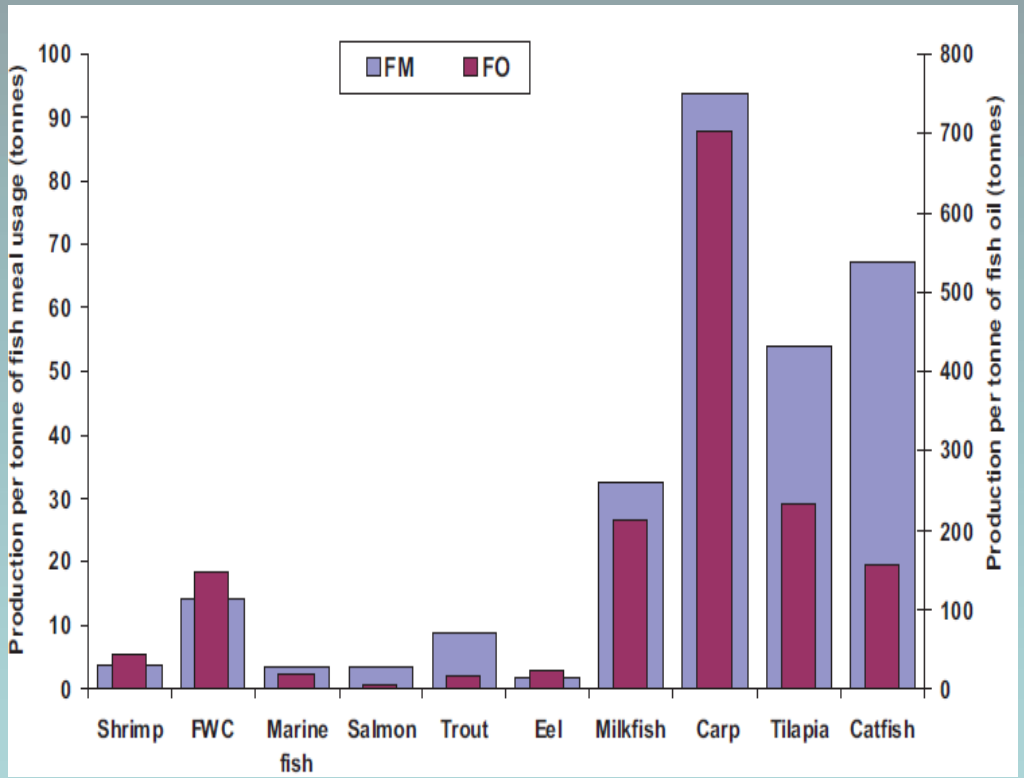
Marine-Harvested Ingredients

- Highest quality protein source commonly available with no essential amino acid deficiencies
- Highly digestible, highly palatable, also serves as a palatability enhancer and/or attractant
- Usually contains about 65% protein that is around 80% digestible
- Also contains fish oil (great source of essential fatty acids) and minerals (from organs and ash)

Marine-Harvested Ingredients

- Inconsistent prices
- Vulnerability to supply shifts
- Perishable, high lipid content speeds spoilage
- Seasonal and geographic variation in quality
- Limited availability
- Vector for environmental contaminants

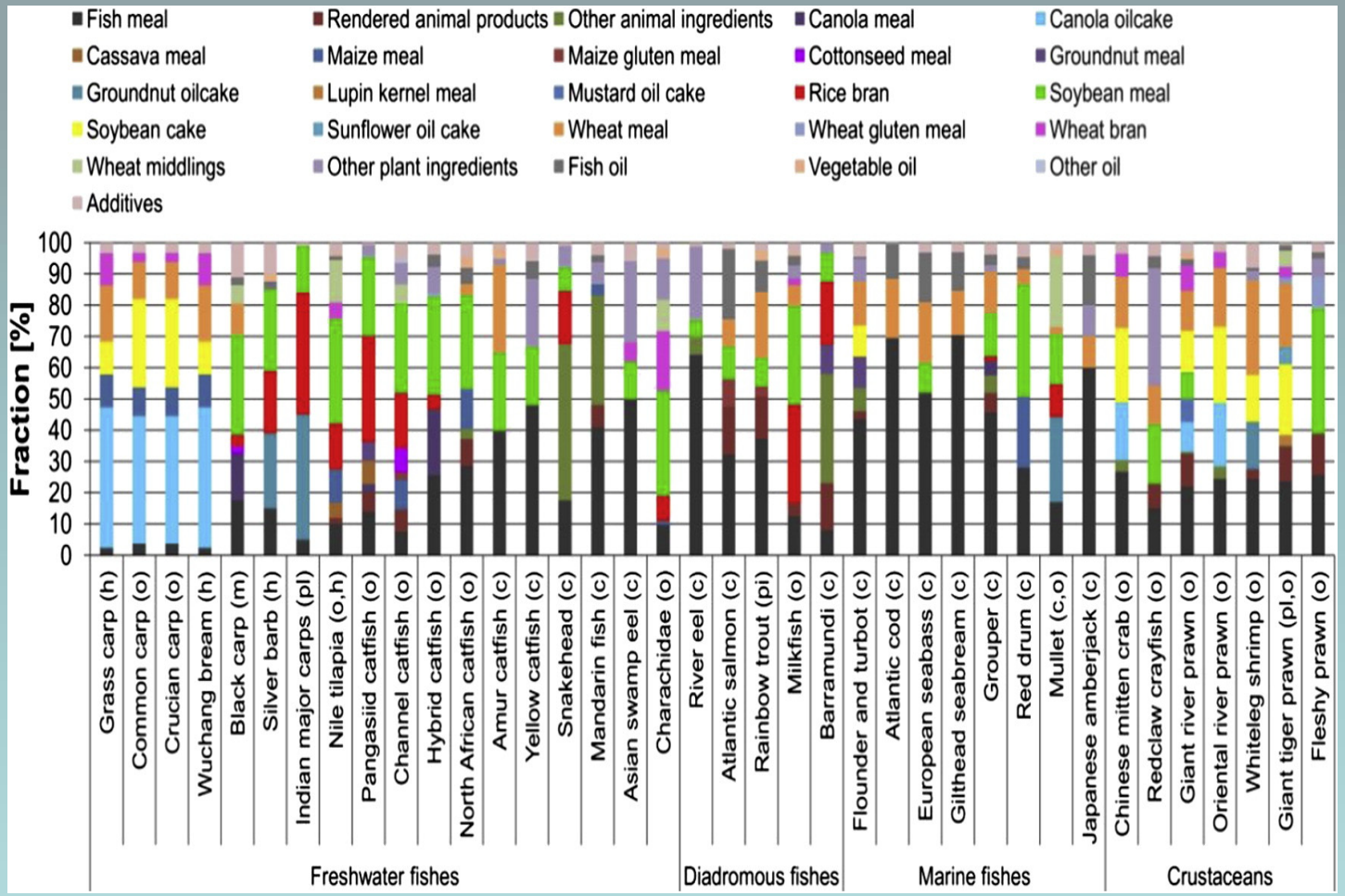
Fishmeal And Oil Use By Species



Aquaculture production per ton of fishmeal and fish oil used in the different cultured groups that are provided with aquafeeds containing these commodities

De Silva and Soto 2009

Composition Of Feed Of Species



Pahlow et al. 2015

1995-2006 % Changes Average Dietary Inclusion Levels for Species Groups

Fishmeal

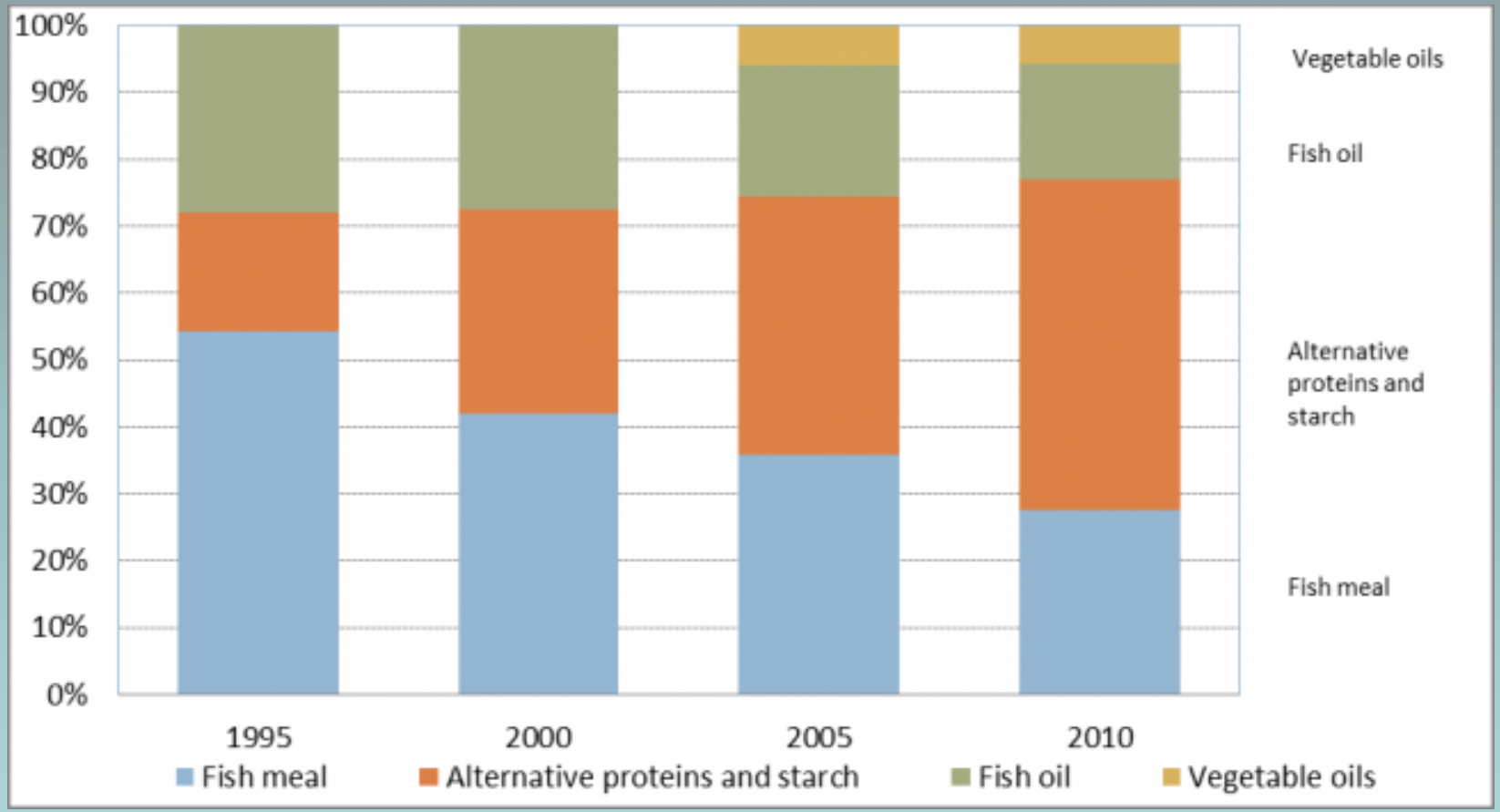
- Marine shrimp 28 to 20%
- Marine fish 50 to 32%
- Salmon 45 to 30%
- Trout 40 to 30%
- Carp 10 to 5%
- Catfish 5 to 10%
- Eel 65 to 55%
- Freshwater crustaceans 25 to 15%

Fish Oil

- Marine shrimp no change (2%)
- Marine fish 15 to 8%
- Salmon 25 to 20%
- Trout 20 to 15%
- Eel 8 to 5%
- Misc. freshwater carnivorous fish 8 to 5%

Tacon & Metian 2008

Salmon Diets



For 2013 inclusion is 15 % fishmeal and the oil content is 1/3 fish oil and 2/3 vegetable oil. Some major producer grower diets are down to 10 % fishmeal)

Figure and data from IFFO

Fishmeal replacement in commercial fish feeds

- Studies have been conducted on almost every cultured species to test fishmeal replacement with other sources of protein, primarily agricultural by-products.

Fishmeal replacement in commercial fish feeds

- Adoption of reduced fishmeal and oil feeds has been historically hindered by a lack of information regarding:
  - The available nutritional value of ingredients
  - Impacts on growth production
  - Effects on feed efficiency
  - Water quality
  - Fish health
  - Product quality

Fishmeal replacement in commercial fish feeds

- Adoption is now occurring incrementally due to
  - Alternative ingredient costs vs FM
  - Government mandates limiting inclusion level
  - Labeling/Marketing values (Whole foods/ other eco-labeling)
  - NGO encouragement (Monteray Bay/F3 prize)

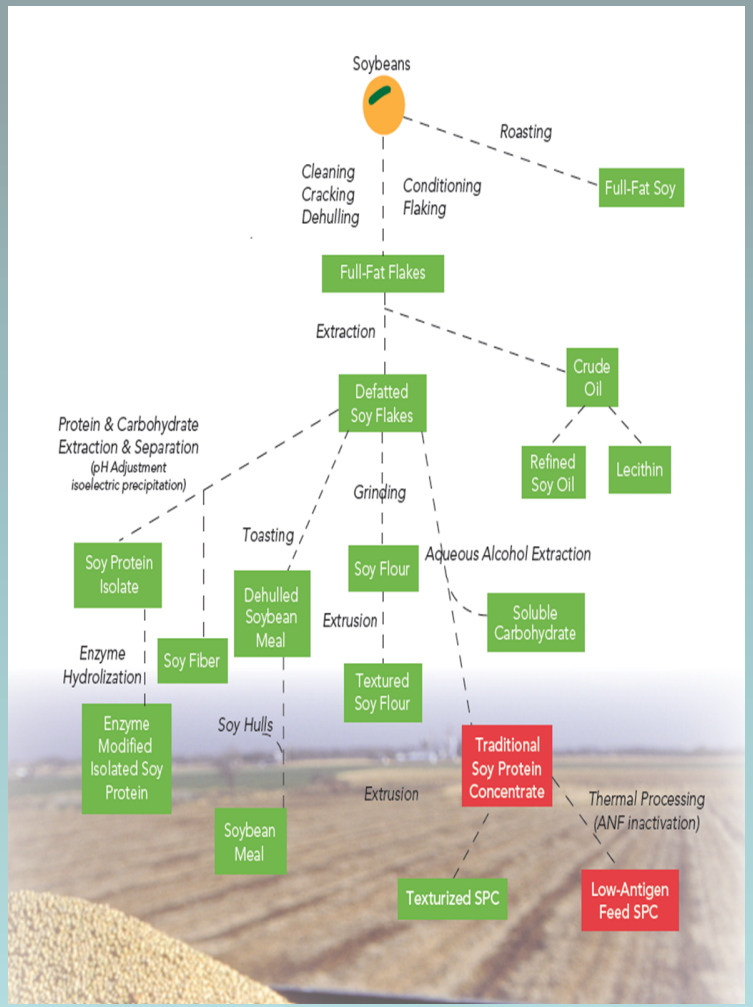
Alternative Ingredient Diversity

Alternative Ingredients

- Increased flexibility is the basis for a more **economic** feed
  - When a raw material becomes too expensive, one can change to an alternative raw material
- Increased flexibility can form the basis of a more **sustainable** feed
  - Especially important for a growing aquaculture industry with limited supply of marine raw materials

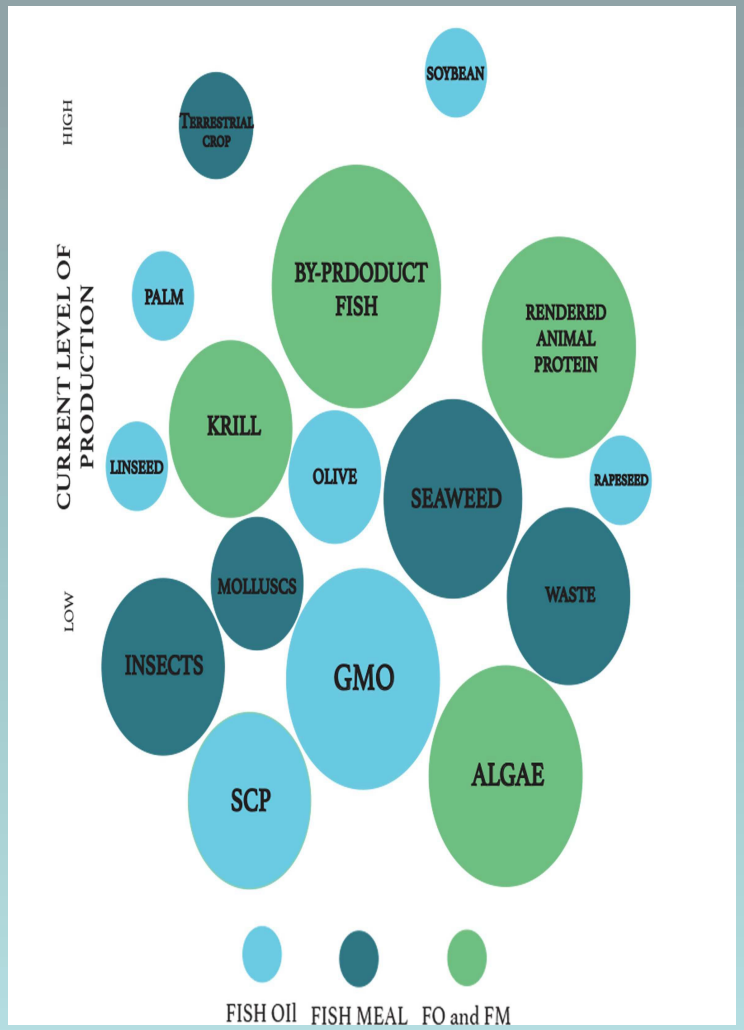
Alternative Ingredients

- By-products from human food production
  - Animal by-products
  - Plant by-products
- Further refinement of “meals” yield concentrates or isolates
  - Provide higher protein density
  - Reduced anti-nutritional factors



U.S. Soybean Export Council 2008

Alternative Ingredients



An overview of alternative ingredients for fishmeal and fish oil, visualized by current level of production and its promise.

Schalekamp et al. 2015

Alternative Ingredient Evaluation; Nutritional Value

1) Compositional analysis
   - Nutrients; protein, energy, amino acids, fatty acids, vitamins, minerals
   - Anti-nutrients

2) First Feeding Fry Screening

3) Palatability; Effect on feed intake

4) Digestibility; Apparent Digestibility Coefficients

5) Functionality; durability, expansion, oil absorption, water stability

6) Growth; gain, FCR, nutrient retention, fecal production, product quality
   laboratory, pilot scale, production scale

Database of Nutrient Digestibility's of Traditional and Novel Feed Ingredients for Trout and Hybrid Striped Bass

F.T. Barrows[1], T.G. Gaylord[2], W. Sealey[2], S.D. Rawles[3]

This is a collaborative project among;

USDA-Agricultural Research Service
National Program 106 - Aquaculture
[1]Trout-Grains Project, Aberdeen and Hagerman ID and Bozeman, MT
[3]H. K. Dupree Stuttgart National Aquaculture Research Center, Stuttgart, AR

USDOI- Fish and Wildlife Service
[2]Fish Technology Center, Bozeman Montana

Rainbow Trout
Over 150 entries currently

Description

The determination of nutrient digestibility's in specific ingredients and diets for fish has been an area of active research for decades. The Apparent Digestibility Coefficients (ADC), the percentage of nutrients in an ingredient that are available to the fish, is information needed by researchers, producers, and feed mills to accurately formulate feeds and thus meet the needs of the animal without excess. ADC's are also necessary for determining the nutritional and economic value of alternative ingredients. Data developed from many different laboratories have been compiled in publications such as the NRC (1993), and often show extreme variability. This is not unexpected since there are many factors that can affect the ADC of an ingredient, including basal diet formulation, method of feed manufacturing (cooking versus cold formation), fecal collection method, etc. Different laboratories often use a mixture of methods specific to that laboratory.

Fish Feed and Nutrition Laboratory (Lab scale Feed Mill), Bozeman, Montana

H.K. Dupree Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas

Nutrient Composition of Ingredients and Reference Diets

NA* - not available

Last updated, May 15, 2011

Experiment 3	Macro-nutrients % Dry weight DM %	Fat %	Protein %	Energy Kcal/kg	Amino Acids % Dry Weight Ala %	Arg %	Asp %	Glu %	Gly %	His %	Ile %	Leu %	Lys %	Met %	Phe %	Pro %	Ser %	Thr %	Tyr %	Val %	Sum AA %	Ca %	Co mg/kg	Cu mg/kg
Soybean Meal, 48% CP	94.1	1.7	51.9	4685	2.39	4.43	6.10	9.40	2.22	1.31	2.34	4.53	2.72	0.66	2.92	2.83	3.03	2.34	2.19	2.80	52.20	0.51	0.21	159.4
Soy Protein Concentrate, Solae Profine VF	96.1	0.0	72.2	4710	3.33	6.32	8.97	14.25	3.28	1.86	3.36	6.05	3.89	1.04	4.04	4.38	4.55	3.37	3.02	4.05	75.77	0.43	0.00	84.3
Barley Protein Conc., Montana Microbial Products	92.7	5.9	56.9	5577	2.52	3.36	3.48	15.37	2.23	1.23	2.29	4.55	1.77	0.95	3.68	7.42	3.02	2.28	2.33	3.49	59.96	0.12	0.22	1940.9
Corn Protein Concentrate, Cargill Empyreal 75	94.2	4.2	81.3	5896	7.87	2.92	5.36	19.98	2.40	1.81	3.36	15.07	1.50	2.06	5.82	9.33	5.39	3.24	5.04	4.47	95.62	0.12	0.15	159.3
Algae, Spirulina, batch 745	93.0	2.2	61.5	4818	4.43	4.74	6.09	9.65	3.00	0.90	3.14	5.28	2.29	1.32	2.90	2.51	3.33	3.10	2.69	4.40	59.77	0.57	1.94	35.5
Algae, spirulina, Carbon Capture Corp.	95.0	0.5	72.7	5252	5.17	5.77	7.38	11.13	3.46	1.07	3.66	6.07	2.77	1.58	3.34	2.86	3.92	3.74	3.20	5.07	70.18	0.34	0.47	34.7
Fish meal, Menhaden, Special Select	93.3	7.6	69.4	5719	4.70	4.78	6.55	9.70	5.60	1.41	2.79	5.12	4.36	2.07	2.88	3.88	3.19	3.17	2.31	3.77	66.28	4.93	0.47	31.1
Krill meal	94.3	22.2	56.3	4659	3.12	3.71	5.97	7.36	2.70	1.17	2.87	4.72	3.50	1.70	4.11	2.80	2.76	2.82	2.45	3.39	55.15	2.44	0.59	286.3
Yeast protein, NuPro, Alltech Inc.	95.0	0.5	48.1	4605	3.25	2.66	5.15	6.53	2.15	1.01	2.20	3.46	3.05	0.73	2.23	1.83	2.84	2.73	1.86	2.97	44.66	0.36	2.00	88.4
Reference diet #3	96.3	14.2	43.1	5361	2.53	2.93	4.20	7.25	1.95	0.90	1.78	3.96	1.95	0.97	2.07	2.43	2.33	1.89	1.66	1.97	40.76	0.30	1.14	259.6

Experiment 4	Macro-nutrients % Dry weight DM %	Fat %	Protein %	Energy Kcal/kg	Amino Acids % Dry Weight Ala %	Arg %	Asp %	Glu %	Gly %	His %	Ile %	Leu %	Lys %	Met %	Phe %	Pro %	Ser %	Thr %	Tyr %	Val %	Sum AA %	Ca %	Co mg/kg	Cu mg/kg
Poultry blood meal, 13	94.2	0.9	98.8	5201	8.67	4.96	11.76	9.33	4.99	6.21	1.39	13.27	7.33	0.76	7.27	3.80	5.07	4.16	2.76	8.84	100.60	0.07	BD	28.0
Poultry blood meal, 8521	90.5	0.7	100.0	6171	9.36	4.77	13.31	8.86	5.41	7.33	0.42	14.93	7.62	0.67	7.83	3.94	5.51	3.69	2.42	10.29	106.39	0.00	BD	17.0
Soybean meal, modified, Hamlet HP-300	92.8	1.3	59.1	4851	2.81	5.02	7.24	11.38	2.68	1.75	2.70	4.88	3.08	0.62	3.40	3.28	3.63	2.69	2.47	3.09	60.73	0.26	BD	94.0
Poultry meal, American Dehydrated Foods	94.0	17.1	78.1	6102	5.18	6.26	7.94	12.15	4.74	2.18	3.83	6.88	5.70	1.69	3.64	3.80	3.87	4.14	3.03	4.54	79.58	0.87	BD	16.0
Fish meal, Menhaden, Special Select	93.1	7.1	66.6	4672	4.59	4.66	6.50	9.57	5.22	1.54	2.79	5.10	4.40	1.39	2.85	3.40	3.10	3.16	2.30	3.61	64.17	5.10	1.60	30.0
Soy protein, bio-fuels coproduct	97.4	1.1	60.0	4515	2.89	4.97	7.19	11.61	2.71	1.51	2.70	4.88	3.15	0.63	3.23	3.35	3.62	2.70	2.37	3.24	60.76	0.29	BD	120.0
Bacterial biomass	96.2	6.6	82.0	5731	6.54	6.01	9.16	11.05	4.19	1.85	4.10	7.81	4.18	1.65	4.30	3.33	3.91	5.40	3.29	6.10	82.87	0.01	BD	41.0
Reference diet #3	97.3	14.6	47.0	5493	2.66	3.83	4.42	7.57	2.37	1.10	2.08	4.45	2.09	0.89	2.43	3.03	2.29	2.07	2.00	2.41	45.69	0.41	0.24	230.0

Experiment 5	Macro-nutrients % Dry weight DM %	Fat %	Protein %	Energy Kcal/kg	Amino Acids % Dry Weight Ala %	Arg %	Asp %	Glu %	Gly %	His %	Ile %	Leu %	Lys %	Met %	Phe %	Pro %	Ser %	Thr %	Tyr %	Val %	Sum AA %	Ca %	Co mg/kg	Cu mg/kg
Fish meal, Menhaden, Special Select	93.0	8.0	67.6	4672	4.64	4.77	6.64	9.56	5.20	1.55	2.82	5.23	4.50	1.39	2.93	3.47	3.18	3.28	2.35	3.66	65.14	5.92	1.29	50.6
Distillers Dried Grains, High protein	93.5	5.4	40.8	5335	3.32	1.69	2.89	7.65	1.41	1.04	1.57	5.84	1.05	0.57	2.33	3.86	2.48	1.90	2.01	2.22	41.83	0.01	BD	38.5
Distillers Dried Grains/solubles, Valero	85.8	10.5	30.5	5452	2.21	1.34	2.04	4.46	1.20	0.75	1.05	3.57	0.82	0.38	1.51	2.46	1.69	1.43	1.30	1.57	27.79	0.03	BD	47.8
Distillers Dried Grains/solubles, Wentworth	84.3	12.9	32.5	5705	2.45	1.60	2.25	4.87	1.30	0.82	1.15	3.91	0.93	0.43	1.67	2.66	1.86	1.56	1.45	1.73	30.63	0.05	BD	48.7
Soybean meal, USDA, variety A	91.9	1.4	50.6	4719	2.33	4.19	6.00	9.50	2.19	1.31	2.05	4.07	2.69	0.52	2.70	2.76	3.04	2.29	1.91	2.47	50.01	0.30	0.13	152.4
Soybean meal, USDA, variety B	91.2	1.2	57.4	4800	2.61	4.73	7.04	11.11	2.52	1.46	2.48	4.65	3.04	0.60	3.13	3.25	3.52	2.60	2.26	2.86	57.85	0.24	BD	164.5
Soybean meal, USDA, variety C	87.5	1.3	56.7	4790	2.62	4.64	7.03	9.42	2.55	1.46	2.49	4.67	3.03	0.62	3.13	3.50	3.49	2.59	2.24	2.88	56.36	0.23	BD	160.0

Palatability & Digestibility

Apparent Digestibility Coefficient, %

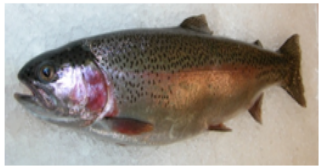
Variable affecting results

- Basal formula
- Inclusion rates
- Feed processing
- Fish size
- Water temperature
- Fecal collection
- Time of collection
- Mathematical calculations
- Dry matter or as-is substitutions
- .....

Common measurement;

46 references in one table in NRC 2011

Nutrients	Poultry by-product
Dry matter	83.7
Protein	84.7
Energy	89.9
Ash	44.2
Organic matter	89.0
His	87.6
Arg	91.6
Tau	85.7
Tyr	84.6
Val	81.1
Met	91.4
Phe	86.1
Ile	80.1
Leu	86.7
Lys	89.9
Phosphorus	41.1



Apparent Digestibility Coefficients*, %, of Ingredients and Reference Diets, Rainbow Trout

Agricultural Research Service — Trout-Grains Project — USDA

U.S. Fish & Wildlife Service

Atlantic salmon
Arctic Char
White Sea bass
Yellowtail

Experiment 3	Macro-nutrients				Amino Acids																Minerals			
	Dry Matter	Fat	Crude Protein	Energy	Ala	Arg	Asp	Glu	Gly	His	Ile	Leu	Lys	Met	Phe	Pro	Ser	Thr	Tyr	Val	Sum AA	P	K	S	Zn
Soybean Meal, 48%CP	75	86	96	81	97	99	95	95	95	97	97	97	97	97	91	96	94	92	98	96	96	10	94	80	20
Soy Protein Concentrate, Solae Profine VF	94	100	100	98	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	35	98	79	89
Barley Protein Conc., Montana Microbial Products	97	100	100	97	96	99	96	98	96	96	100	99	94	99	100	99	97	96	100	97	98	82	92	84	51
Corn Protein Concentrate, Cargill Empyreal 75	95	92	89	91	91	92	87	90	85	87	88	91	88	92	91	91	91	86	92	88	90	58	68	78	100
Algae, spirulina, batch 745	78	85	81	75	79	78	81	85	84	82	84	80	88	91	78	87	79	87	86	75	82	84	94	55	8
Algae, spirulina, Carbon Capture Corp.	84	70	80	83	82	74	83	82	88	88	87	86	90	95	87	95	85	90	89	76	84	92	97	61	100
Fish meal, Menhaden, Special Select	98	100	92	100	93	95	89	95	85	94	98	99	94	95	96	92	94	95	99	96	94	57	98	97	75
Krill meal	85	99	84	92	93	93												83	45	90	82	60	89	73	55
Yeast protein, NuPro, Alltech Inc.	20	6	37	25	54	59												31	51	37	46	63	96	10	-21
Reference diet #3	76	98	87	82	91	95												89	93	90	90	74	96	68	22

Experiment 4	Macro-nutrients				Minerals			
	Dry Matter	Fat	Crude Protein	Energy	P	K	S	Zn
Poultry blood meal, 13	78	0	79	73	100	94	23	100
Poultry blood meal, 8521	79	0	77	75	100	93	47	66
Soybean meal, modified, Hamlet HP-300	68	14	90	71	43	95	44	65
Poultry meal, American Dehydrated Foods	100	95	98	99	78	95	66	68
Menhaden fish meal, Special Select	70	82	85	90	34	90	62	4
Soy protein, bio-fuels coproduct	54	0	91	65	0	93	35	0
Bacterial Biomass	81	91	89	85	65	0	45	100
Reference diet #3	76	99	86	83	61	95	65	20

Experiment 5	Macro-nutrients				Amino Acids																	Minerals			
	Dry Matter	Fat	Crude Protein	Energy	Ala	Arg	Asp	Glu	Gly	His	Ile	Leu	Lys	Met	Phe	Pro	Ser	Thr	Tyr	Val	Sum AA	P	K	S	Zn
Fish meal, Menhaden, Special Select	79	89	91	99	91	95	95	96	79	97	99	100	97	95	93	83	94	96	98	96	94	45	93	81	56
Distillers Dried Grains, High protein	52	79	83	59	84	89	70	83	56	82	78	90	69	75	67	83	73	67	88	77	80	89	84	41	0
Distillers Dried Grains/solubles, Valero	50	79	88	59	92	99	91	95	81	90	89	97	79	99	82	92	88	78	95	86	91	72	94	48	0
Distillers Dried Grains/solubles, Wentworth	40	83	81	54	82	90	69	83	57	79	76	86	68	85	68	80	77	72	88	76	78	66	95	56	49
Soybean meal, USDA, variety A	61	37	91	67	91	96	90	89	86	90	90	90	93	88	87	85	87	84	91	86	89	33	93	95	130
Soybean meal, USDA, variety B	57	45	86	66	85	92	83	87	81	86	85	85	88	79	81	84	84	79	88	83	85	19	95	67	87
Soybean meal, USDA, variety C	70	100	96	75	98	99	92	96	94	97	97	97	97	100	90	94	96	93	99	96	96	33	95	73	79
Soybean meal, ADM	30	76	77	72	78	91	75	83	70	81	83	79	86	76	67	76	82	74	85	80	80	5	94	34	0
Soy Protein Concentrate, Selecta 60	53	70	90	67	93	99	84	93	84	92	94	96	94	97	86	91	93	88	98	93	92	29	95	70	52

Database of Nutrient Digestibility's of Feed Ingredients for Trout and Hybrid Striped Bass

Availability;

1) Mini-CD available

2) Posted on Web

Search; ARS Trout-Grains Digestibility

3) Direct contact; email

wendy_sealey@fws.gov

Updates;

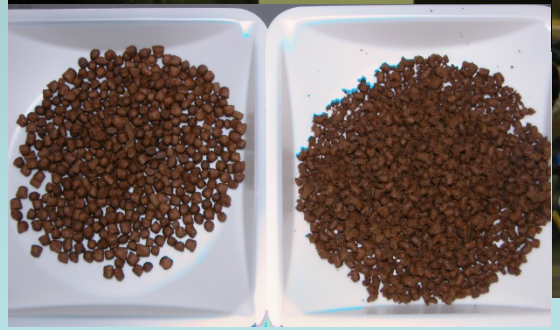
Will be made on web page as soon as new information is available

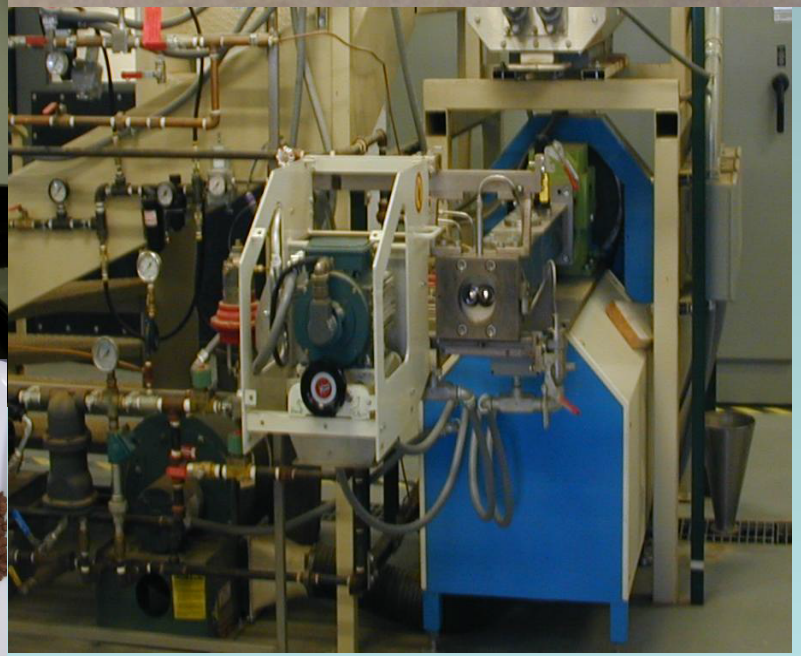
Mini-CD are direct linked to the updates

Ingredient Evaluation;
Functionality

Pellet Quality

- durability
- expansion
- oil absorption
- water stability





Alternative Ingredient Evaluation;
First Feeding Fry Screening

Designed to have the greatest impact of test ingredient and decrease time required to detect differences.

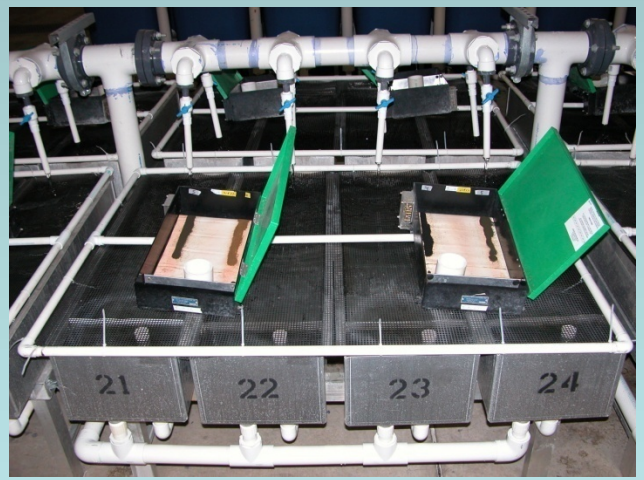
Control diet is 65% high quality sardine meal

Test ingredient replaces 90% of protein from fish meal

Diets are extruded and crumbled

100 fish per tank, 4 tanks per diet

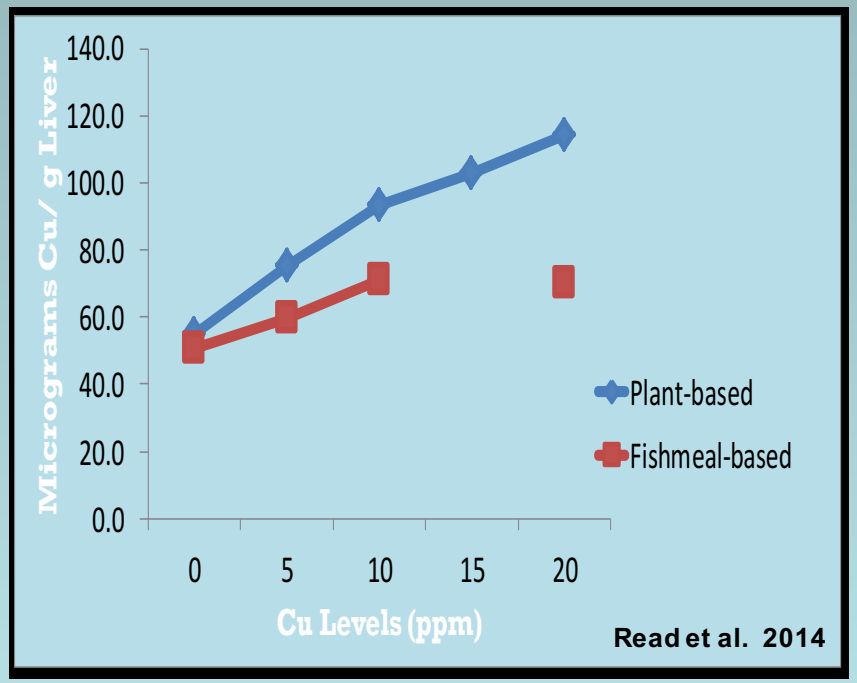
Fed to excess with belt feeders 14 hrs/d



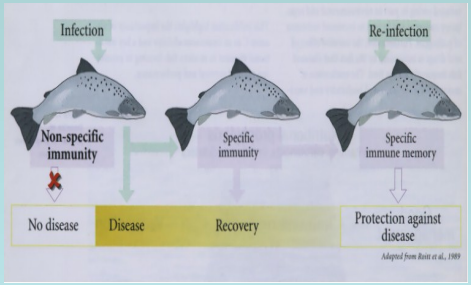
Ingredient Evaluation;
Feeding trials

Ingredient Evaluation;
Fish Health

nutritional pathology
nutritional inadequacy

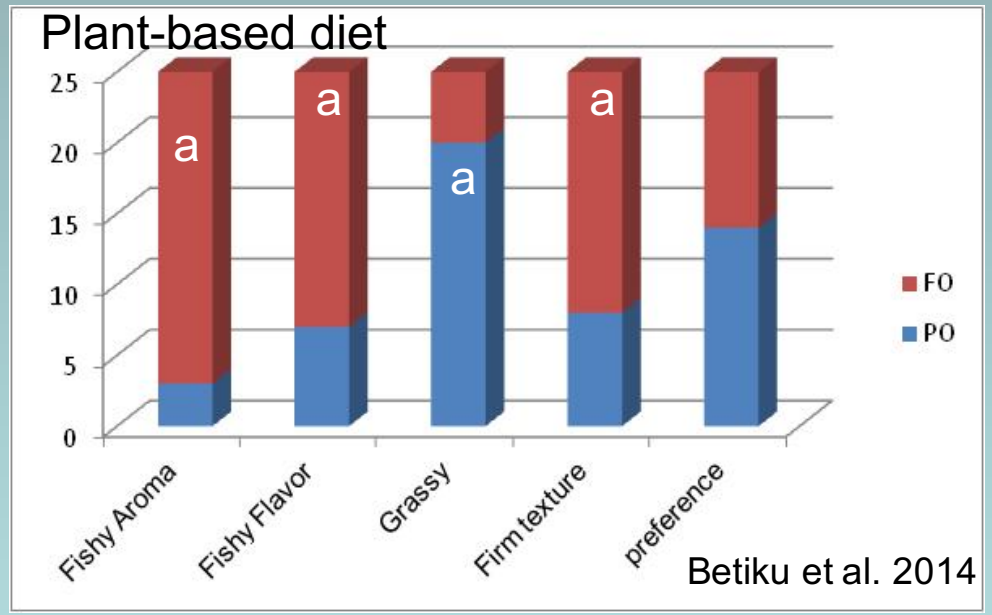


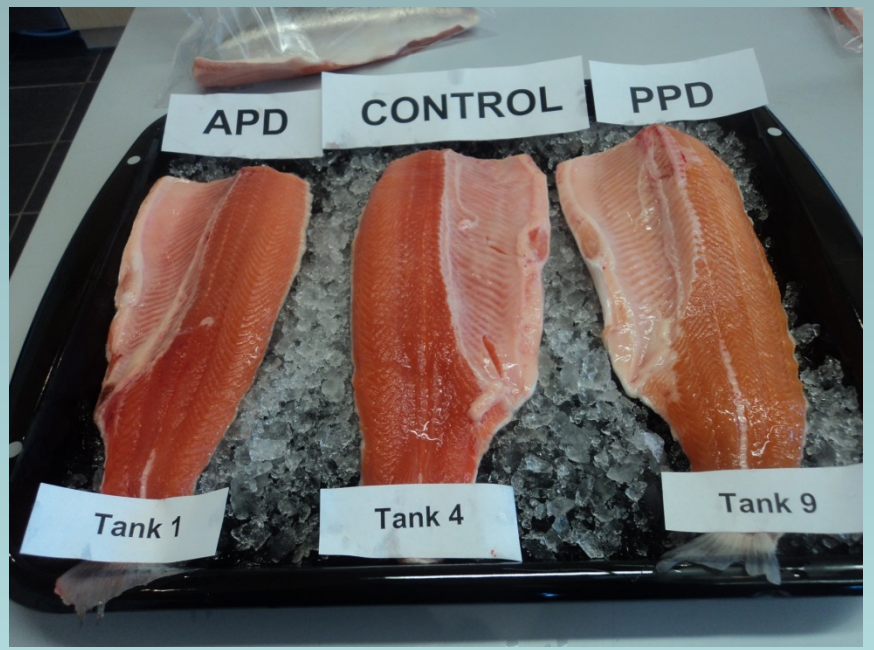
Mortality following experimental challenge with *Flavobacterium psychrophilum*. (Sealey et al. 2011)	
Diet	**% Mortality**
Control	91
Chicken 42	80
Chicken 42/Chicken 70	87
Chicken and Egg Concentrate	85
Pr > F[d]	0.6829
Pooled SE	5.87



Ingredient Evaluation;
Product Quality

color, flavor, texture
consumer acceptance





Ingredient Evaluation;
Effect on Waste Management

Emerging Sources Of Ingredients

Fuel industry co-products

Fishery processing products

Improved plant products

Nut products

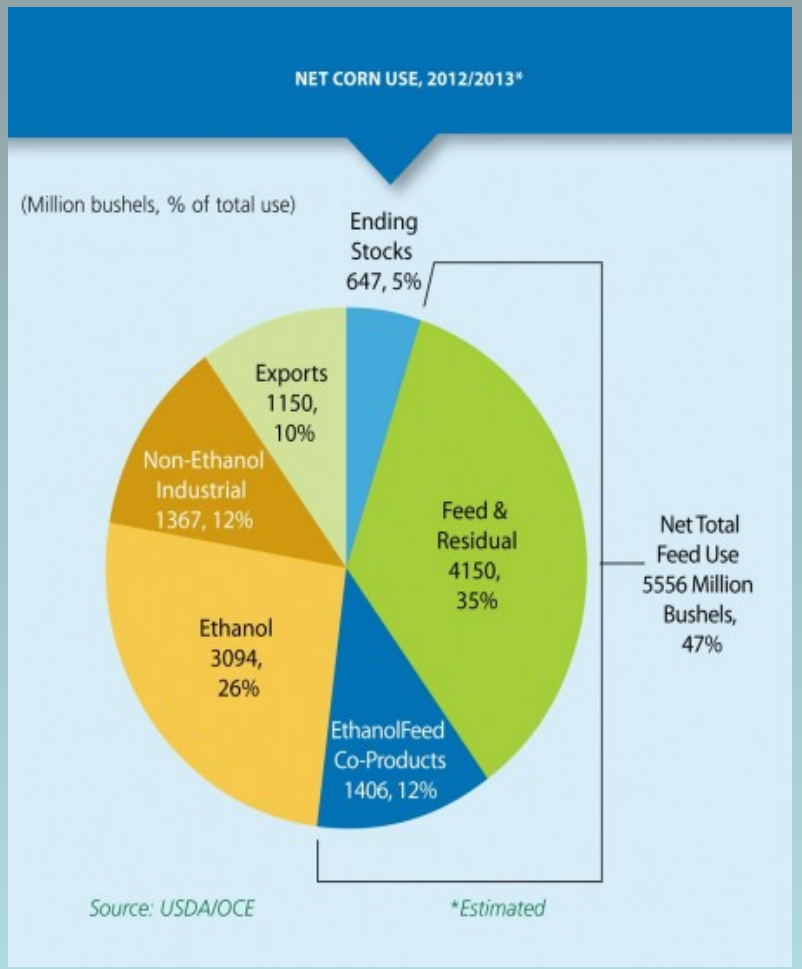
Single cell proteins

Algal/aquatic plants

Insect meals

Fuel Industry Co-Products

Increased more than thirteen-fold from 2000-2013



Grain Distiller's Dried Yeast

Hauptman et al. 2014ab

Sealey et al. 2014a

Distiller's Dried Grains with Solubles

Sealey et al. 2014b

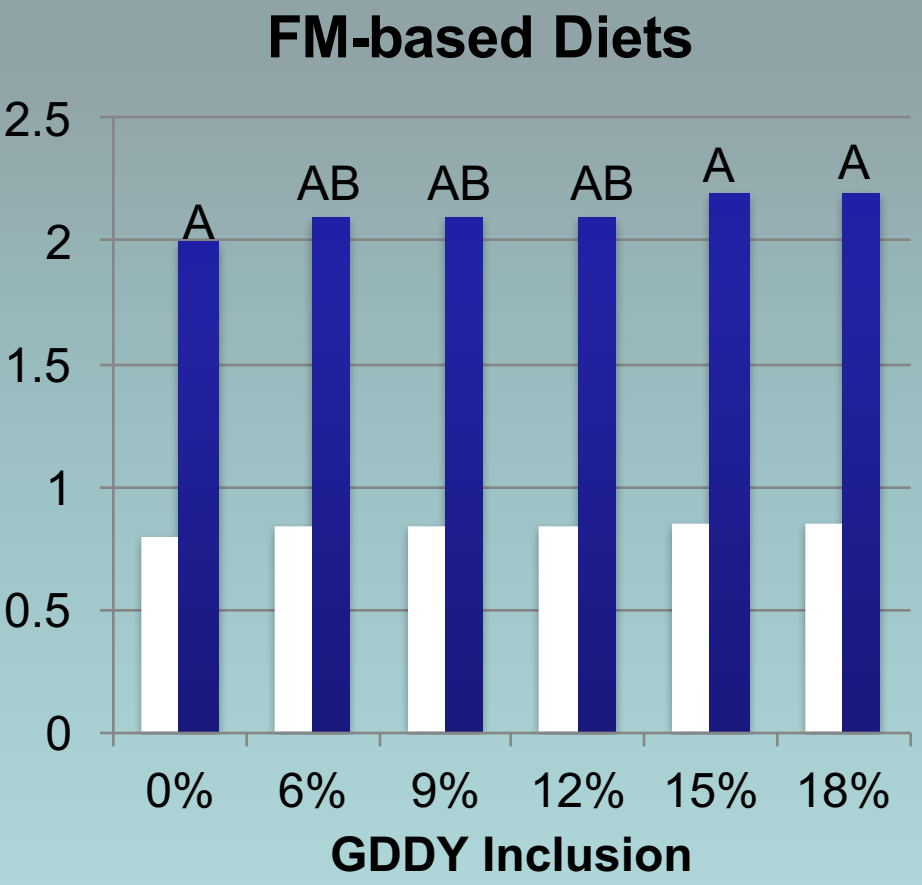
Grain Distiller's Dried Yeast

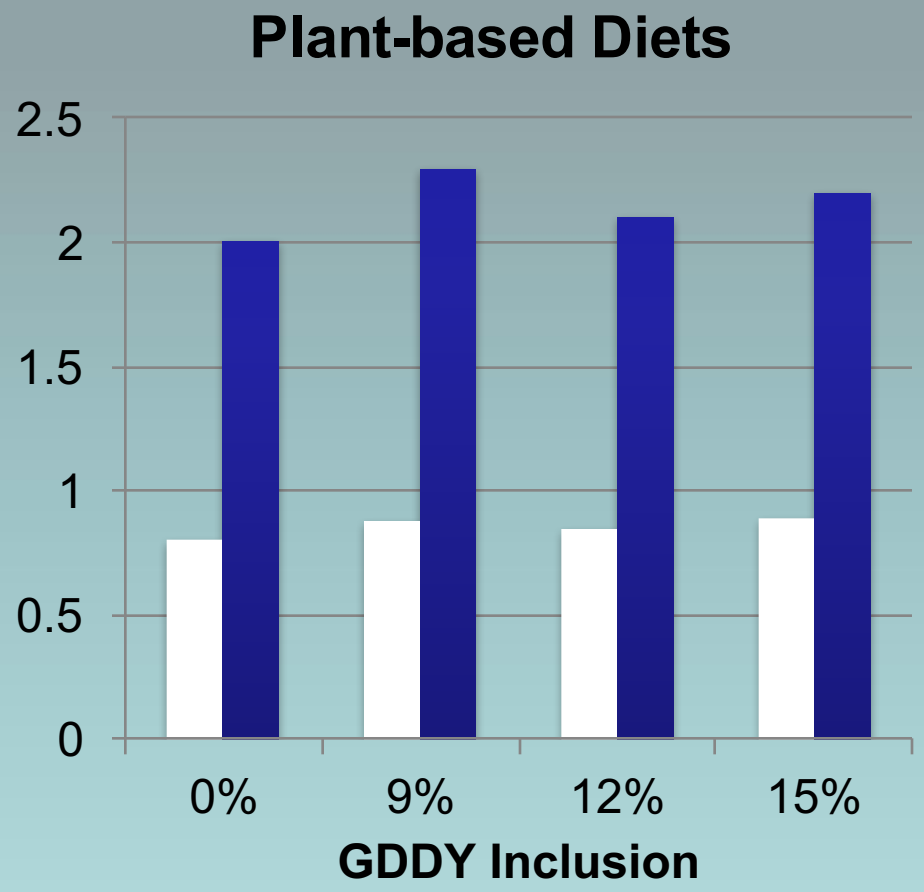
Item, % Dry wt basis	FM	EY
DM	93.45	94.45
Fat	11.73	7.31
Crude Protein	63.42	46.59

- ADCs for DM, Protein, Fat, Energy and AAC for P were 65.4, 97.6, 100, 69.7, and 80.7 respectively

- AACs for Lysine, Methionine, Threonine and Sum of AA were lower than the FM average

Grain Distiller's Dried Yeast





FCR, P = 0.218

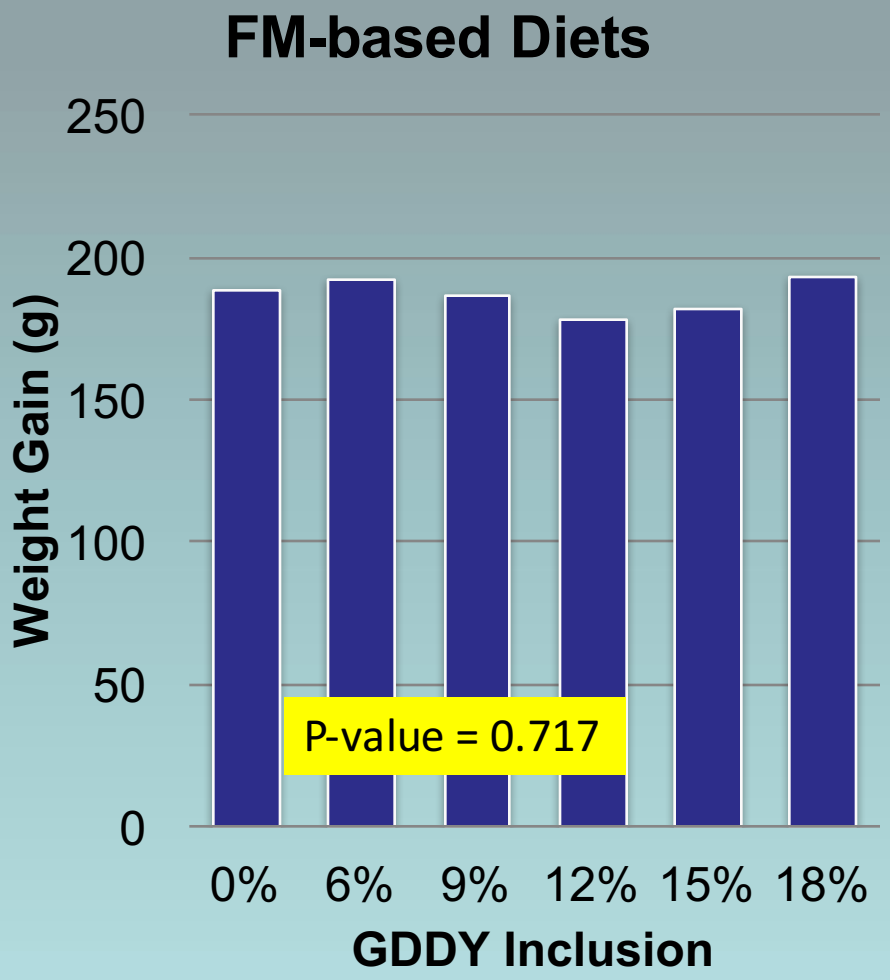
Feed Intake, P = 0.019

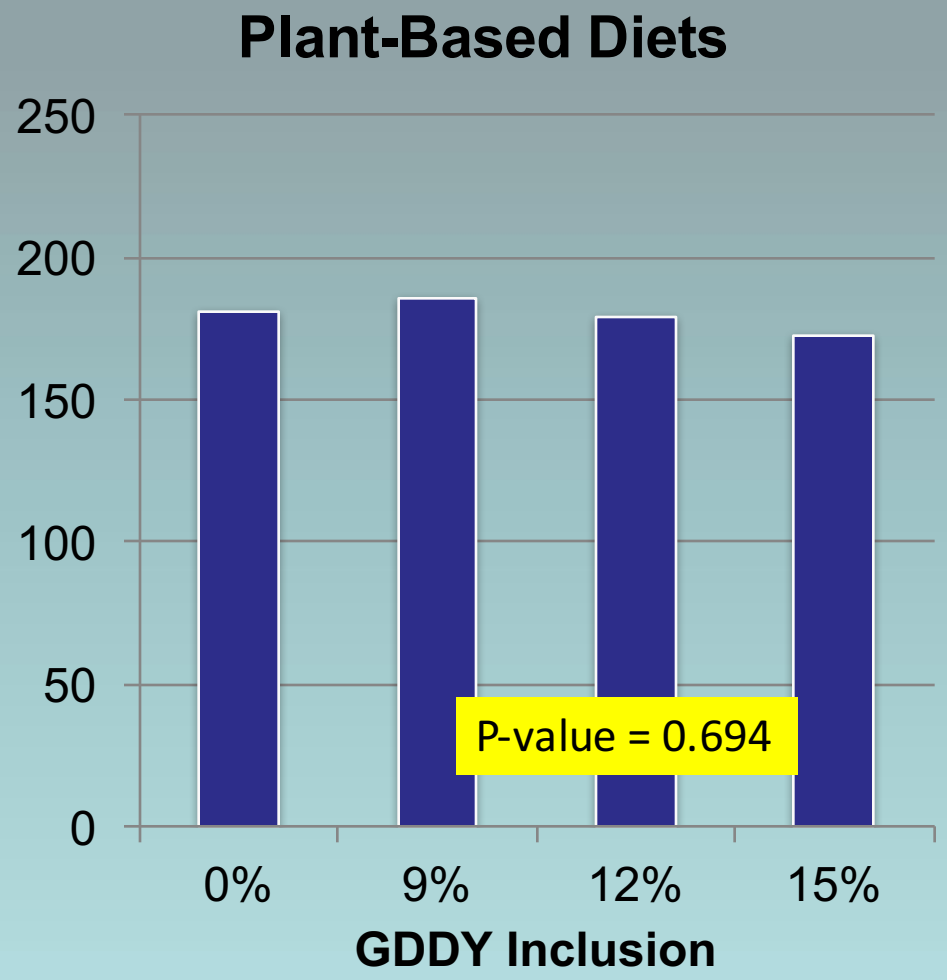
FCR, P = 0.358

Feed Intake, P = 0.064

Sealey et al. 2014a

Grain Distiller's Dried Yeast





Sealey et al. 2014a

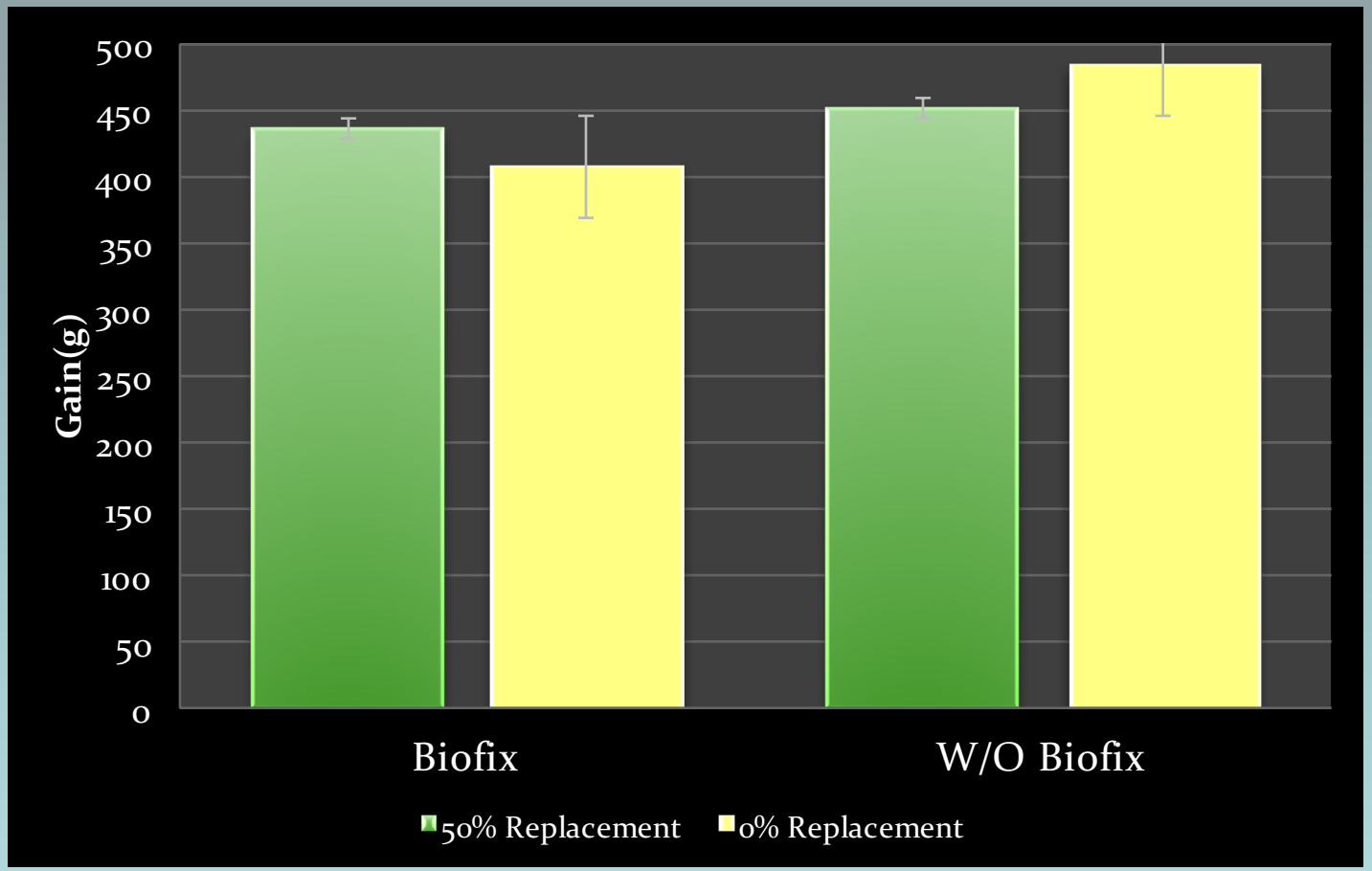
DDGS

	Ingredients			
Proximate Composition		HPDDG	Valero	Wentworth
(%DM)	Dry Matter	93.54	85.82	84.27
	Protein	40.82	30.46	32.50
	Lipid	5.41	10.45	12.94
	Energy (kcal/kg)	5335	5452	5705

ADCs		HPDDG	Valero	Wentworth
	Dry Matter	52	50	40
	Protein	79	79	83
	Lipid	83	88	81
	Energy (kcal/kg)	59	59	54
	Phosphorus	80	91	78

DDGS (% growth increase)

Controlled for pellet quality



Sealey et al. 2014b

Protein: P=0.9130

Supplement = 0.0561

PxS: P=0 .1882

Modification, Enhancement and Development of Ingredients

Soybean meal,

48% crude protein, anti-nutritional factors, intestinal enteritis limits inclusion, $450/ton

Enhanced Soybean meal

58-62% crude protein, reduced ANFs, feed grade, only fat extraction

ultra low oligosaccarides, 6% to 0.1%

UL trypsin inhibitor, ~55,000 to ~1,000

high protein

Schillinger Genetics project to identify and develop cost effective products equivalent to SPC, by crossing and evaluating non-GMO lines of soybeans.

SCHILLINGER GENETICS

Soy Varieities

First Feeding Fry Screening

Grams per fish

4
3.5
3
2.5
2
1.5
1
0.5
0

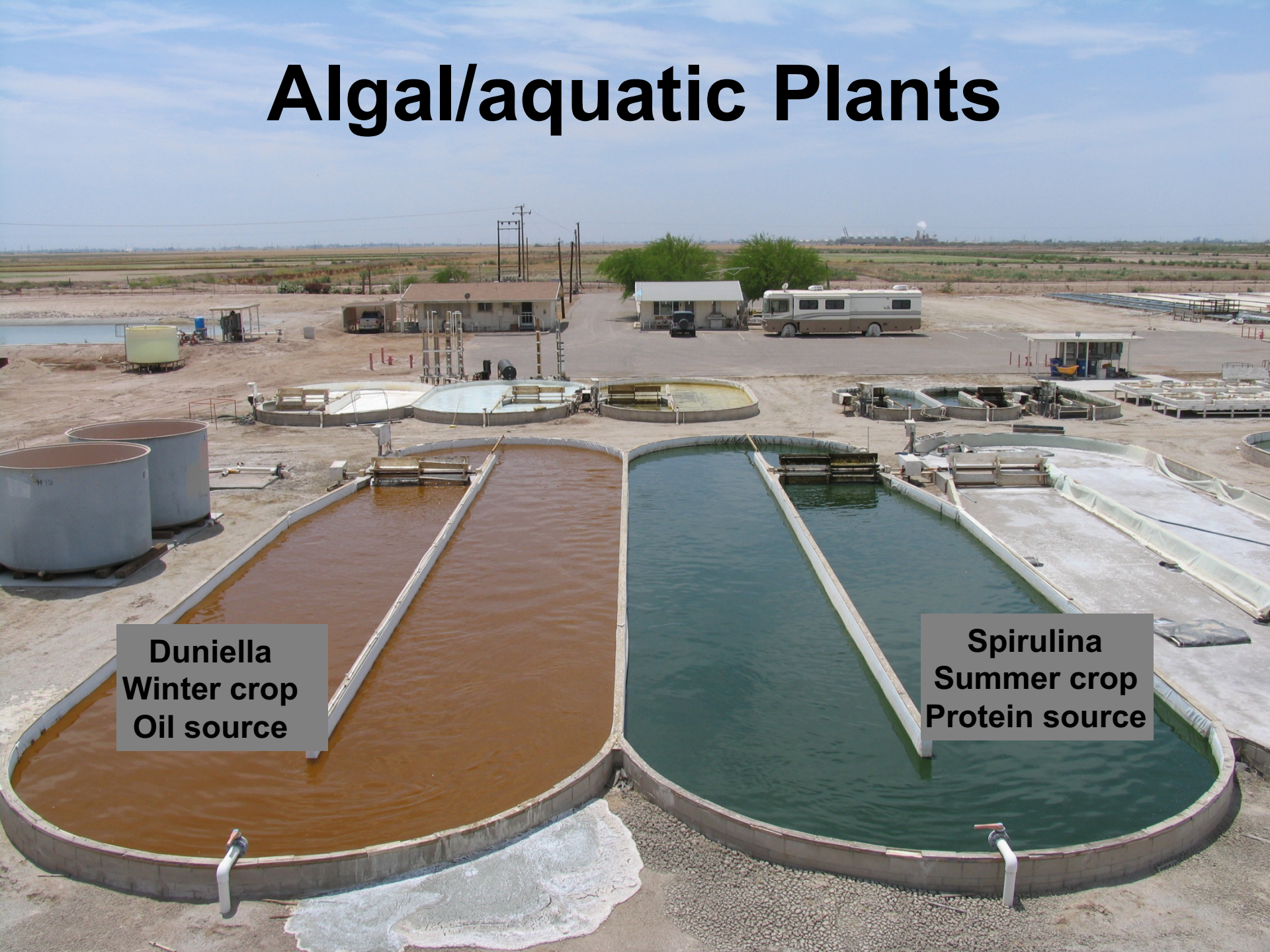
initial
3 weeks
6 weeks

A
B
C

Fish meal A
ULO 3010 A
SPC A
K419 B
204 C
CC C
WF C

No heat treatment

Algal/aquatic Plants



Ingredient Evaluation;
Nutritional and Economic Value

Solar dried, pond produced Spirulina;
Imperial Aquafeeds

1) **Palatability trial;** significant increase feed intake

2) **Apparent Digestibility Coefficients, %**

	Dry matter	Protein	Fat
Reference diet	76.3	86.6	98.3
Spirulina, Imp Aqua	77.8	80.5	96.0
Soybean meal, 48	75.3	85.8	98.1

3) **Functionality;** dramatic expansion, increased pellet durability
increased oil absorption capacity

4) **Growth trials**

a) laboratory, protein blend approach
yellowtail, white sea bass, and salmon

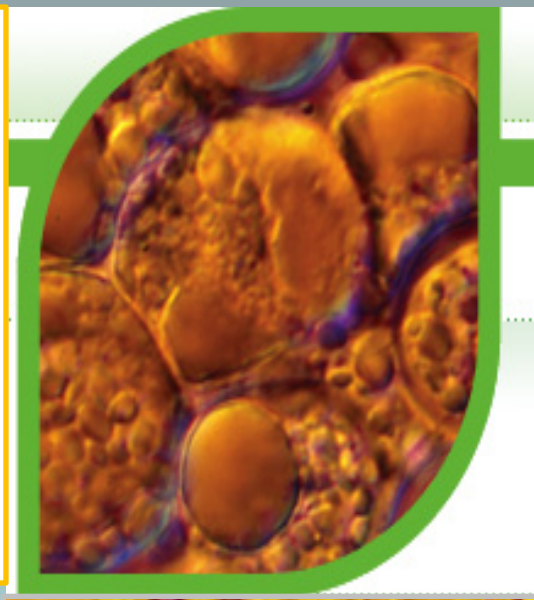
DHA-Gold

DHA-GOLD:

- an algae-based lipid source containing 46% docosahexaenoic acid (DHA, 22:6n-3)
- an algae strain *Crypthecodinium cohnii* which is a natural producer of DHA

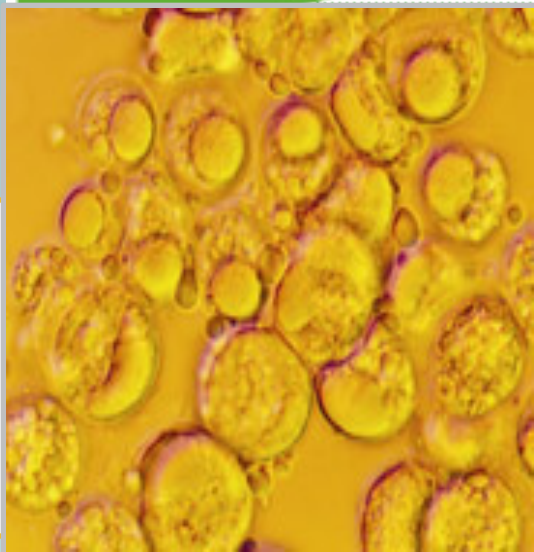
Previous Studies:

- **juvenile cobia** (Salze et al., 2010); juvenile barramundi (Glencross and Rutherford, 2011)



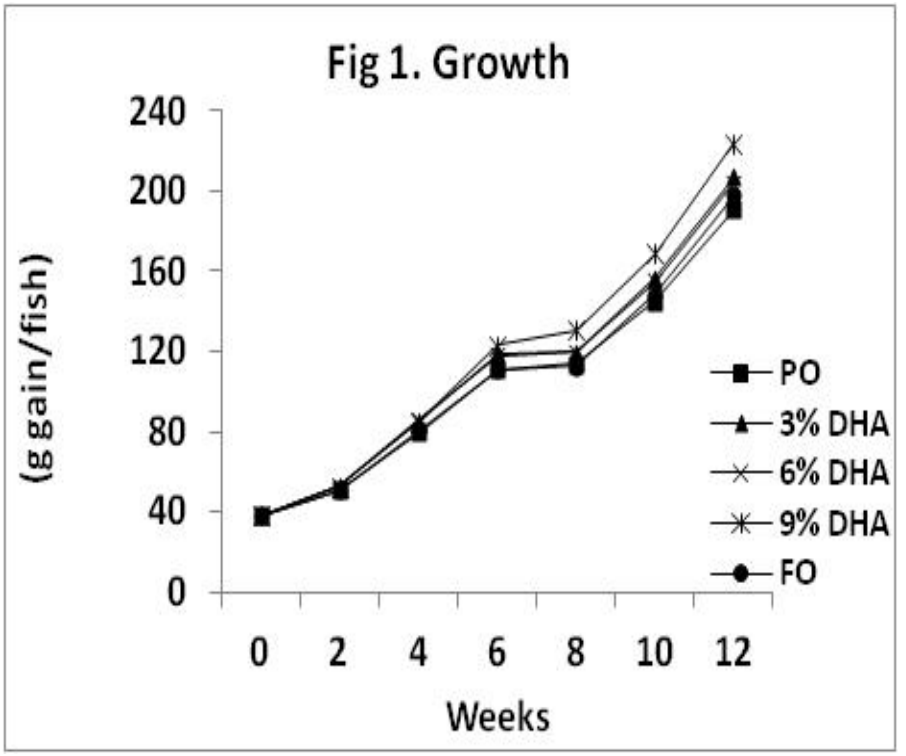
This Study:

Investigated the fillet fatty acid profile, texture, sensory analysis, and growth performance of rainbow trout fed experimental diets with DHA-Gold as a replacement for fish oil

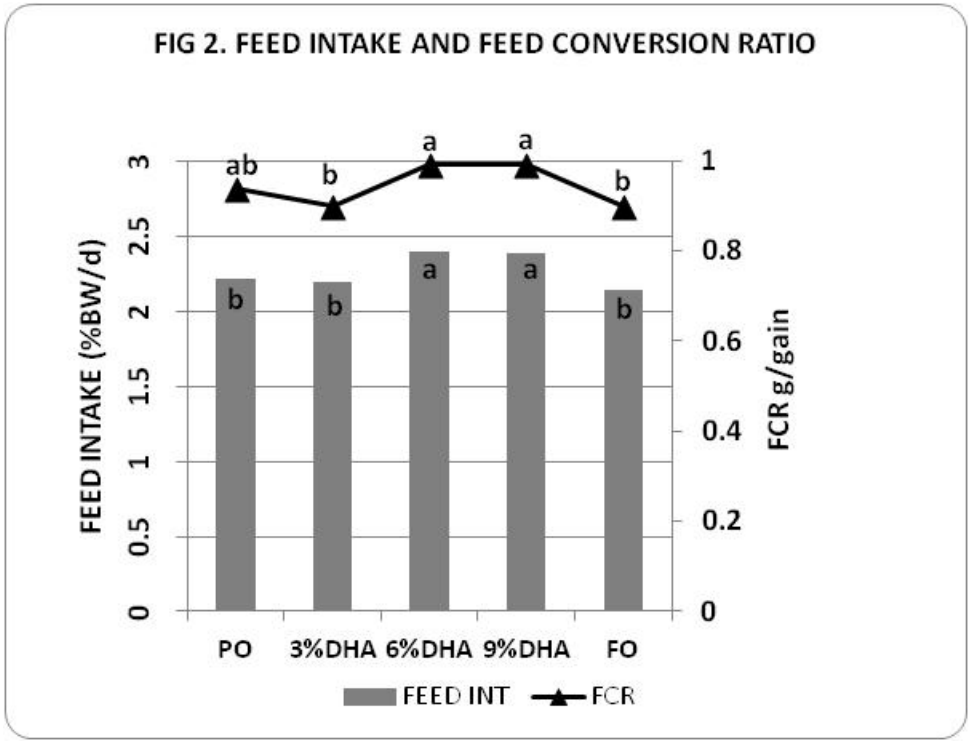


DHA-Gold

Growth of rainbow trout during 12 Weeks feeding experiment



Feed intake of rainbow trout 12 Weeks feeding experiment



Betiku et al. 2014

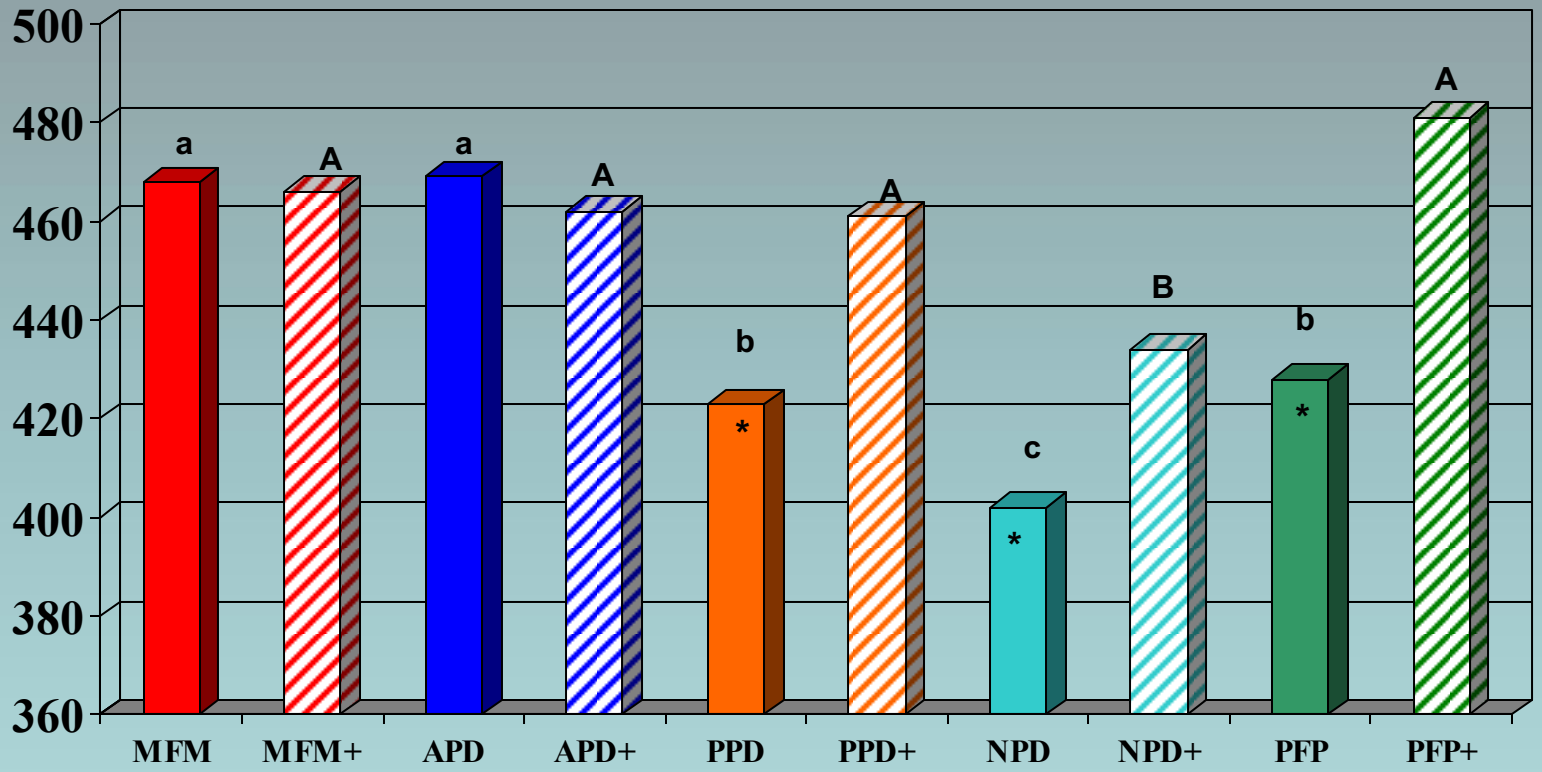
The Importance of Nutrient targets

						NRC						Ideal Protein
	FMD	APD	PPD	NPD	PFP	Target	FMD+	APD+	PPD+	NPD+	PFP+	Target
CP dry	45.4	45.1	45.2	45.7	45.3	45	41.29	40.16	40.40	40.53	41.00	~40
Lipid	20	20	20	20	20	20	20	20	20	20	20	20
DP dry	40.2	39.9	42.2	40.8	41.8	40	36.9	37.3	38.1	36.8	38.0	36
Energy	4919	4788	4991	4519	5194		4613	4605	4618	4191	4825	
Total P	1.19	0.98	1.03	1.05	1.17		1.18	1.01	1.07	1.14	1.14	
Avail-P	0.53	0.53	0.52	0.53	0.53	0.52	0.53	0.52	0.53	0.53	0.53	0.52
Arg	2.55	2.86	2.86	2.52	2.77	2.00	2.11	2.36	2.33	2.35	2.26	2.88
His	1.02	0.93	0.96	1.03	0.94	0.70	0.83	0.86	0.76	0.85	0.75	1.33
Ile	1.58	1.42	1.78	1.73	1.91	0.8	1.30	1.43	1.43	1.43	1.56	1.95
Leu	4.62	3.95	5.14	5.44	4.36	1.40	3.78	3.58	4.04	3.83	3.55	3.42
Lys	2.02	1.85	1.82	1.80	1.89	1.80	3.82	3.82	3.81	3.82	3.82	3.82
Met	1.10	1.10	1.14	1.10	1.10	1.10	1.30	1.30	1.30	1.30	1.30	1.30
Phe	2.21	2.08	2.52	2.52	2.41		1.82	1.84	2.01	1.94	1.97	1.97
Thr	1.67	1.53	1.64	1.64	1.72	0.80	2.14	2.14	2.14	2.14	2.14	2.14
Val	2.28	2.17	2.11	2.13	2.32		1.87	2.02	1.70	1.73	1.90	2.29

Protein reduction with AA supplementation

- Diets were formulated in as a 5X2 factorial design.
  - Five ingredients combinations:
    - 1) (Fishmeal Diet, FMD)
    - 2) (Animal Product Diet, APD)
    - 3) (Plant Product Diet, PPD)
    - 4) (Novel Plant Protein Diet-NPD)
    - 5) (Plant Products with Future Potential-PFP).
  - Two nutrient concentrations were targeted:
    - 1) To meet amino acid targets of Rainbow trout (NRC 1993) utilizing approximately 45% crude protein (40-42% digestible protein)
    - 2) To meet the ideal amino acid balance of rainbow trout muscle for Lys, Met and Thr utilizing approximately 40% crude protein (37-38% digestible protein)

Benefits of AA supplementation

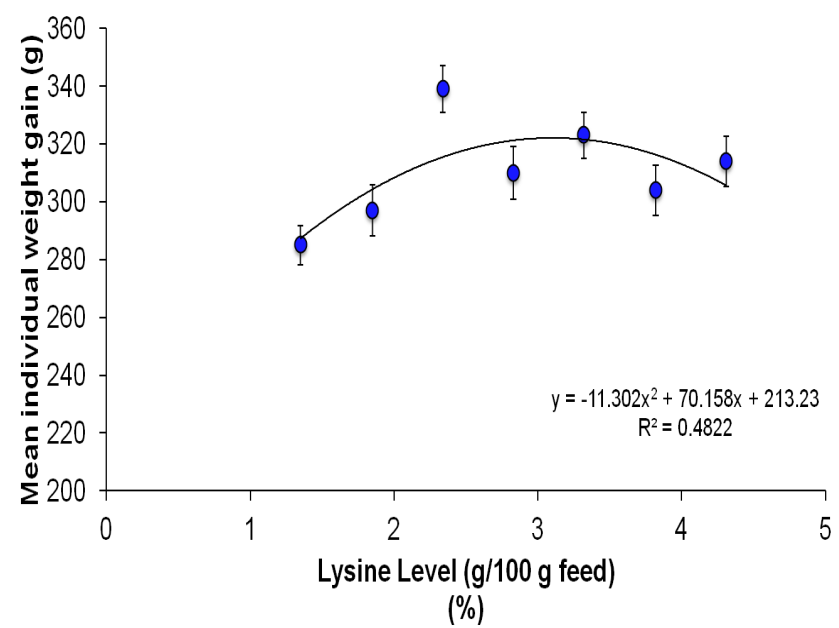


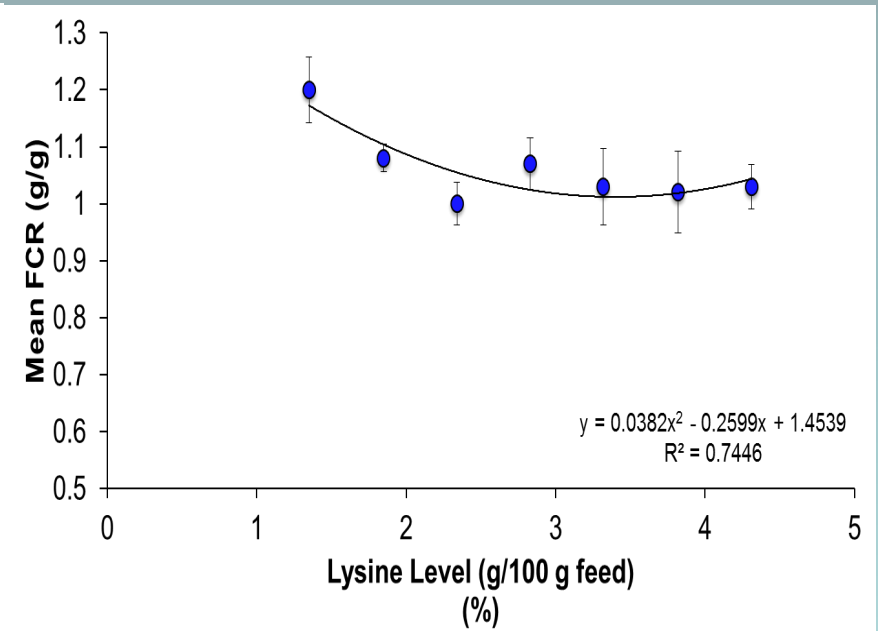
Pr>F	
Ingredient	0.0001
Targets	0.0001
Interaction	0.0006

Refining the lysine supplementation levels for rainbow trout fed a plant-based diet (CSU)

- Diets were formulated on a 40% crude protein (37-38% digestible protein and 20% CL.
- Lysine levels were 1.35, 1.85, 2.34, 2.83, 3.32, 3.82, and 4.31 % of the diet
- Levels encompass and exceed both the NRC 2011 lysine requirement which ranges from 1.3 to 2.5% of diet and the ideal protein lysine level of 3.82% of the diet.).

Refining the lysine supplementation levels for rainbow trout fed a plant-based diet





Optimal' lysine level was 3.10% for weight gain.
Optimal' level predicted to be 3.40% for FCR.

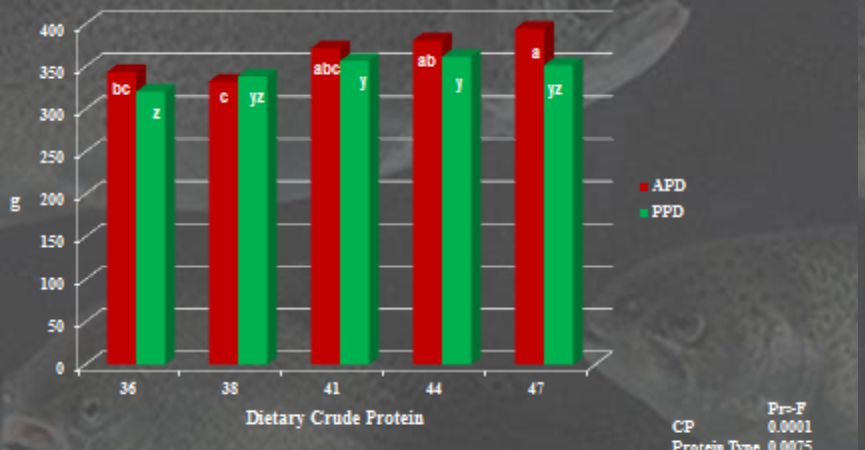
Defining the lower limit of protein reduction when formulating on an Ideal Protein Basis in animal and plant based diets

- 2 X 5 Factorial design was used with two protein sources: an Animal Blend and a Plant Blend
- 5 nutrient targets were set (45, 40, 35, 30 and 25% protein with 20% lipid).

Defining the lower limit of protein reduction when formulating on an Ideal Protein Basis in animal and plant based diets

Final Fish Weight

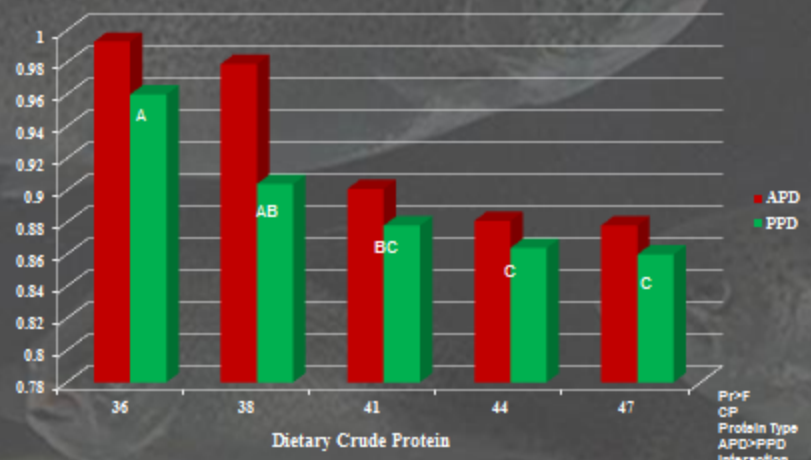
Above 41% crude protein (37% digestible protein) did not improve weight gain



	Pr>F
CP	0.0001
Protein Type	0.0075
APD>PPD	
Interaction	0.0203

Feed Conversion Ratio (g feed / g gain)

Above 41% crude protein (37% digestible protein) yielded no further improvement in FCR



	Pr>F
CP	0.0088
Protein Type	0.0001
APD>PPD	
Interaction	0.2714

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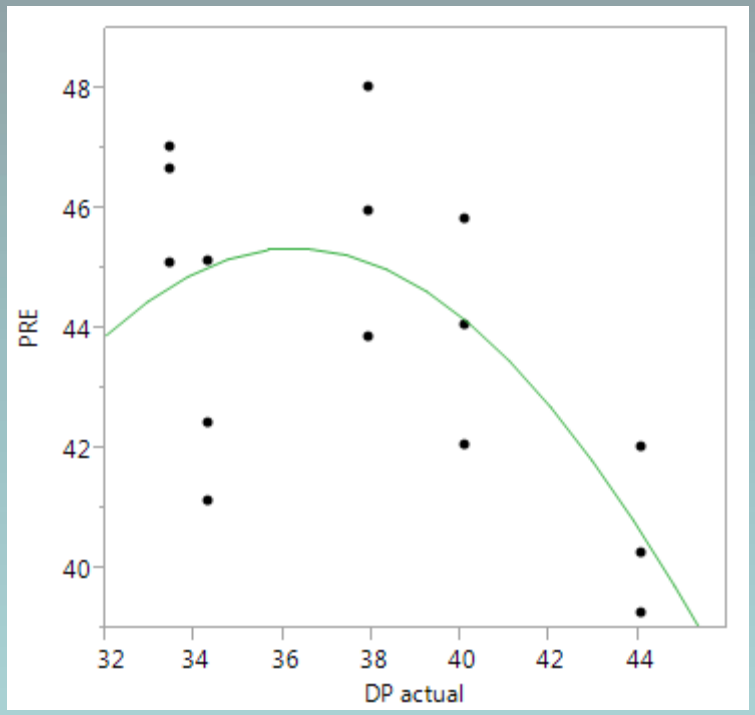
USDA

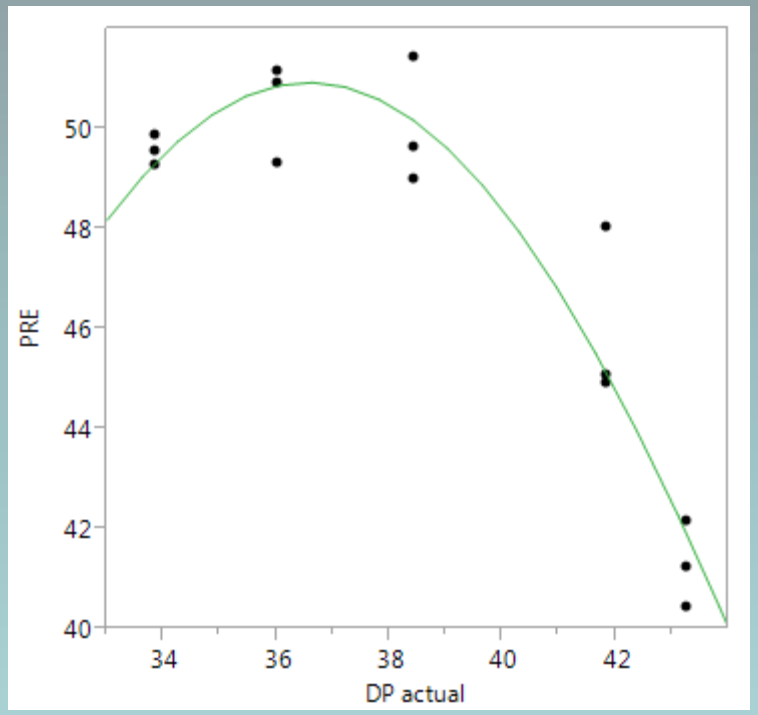
Protein Retention Efficiency

APD



Critical value of 36.2% DP
$R^2 = 0.448$

PPD



Critical value of 36.6% DP
$R^2 = 0.910$

Conclusions

- **Fishmeal protein is not necessary in rainbow trout feeds.**
- **An assortment of alternative ingredients including plant-based proteins and animal protein can be used when appropriate supplementation is used.**
- **Nutritional value of alternative ingredients is required.**
- **Alternative ingredient diets are formulated on an available amino acid basis and amino acid targets are met.**
- **Effects of alternative ingredients on fish performance, fish health and product quality must be determined.**

Acknowledgements

- USDA Staff
- USFWS Staff
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- WSU Staff and students
- U of I Extension Staff

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- Jason Mann (EWOS)
- Skretting

Optimizing Diets for Rainbow Trout

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https://www.fws.gov/mountain-prairie/fisheries/ftc.php

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