Feed Ingredients and the Reduction of Dependence on Marine-Harvested Products for Aquauculture Feeds

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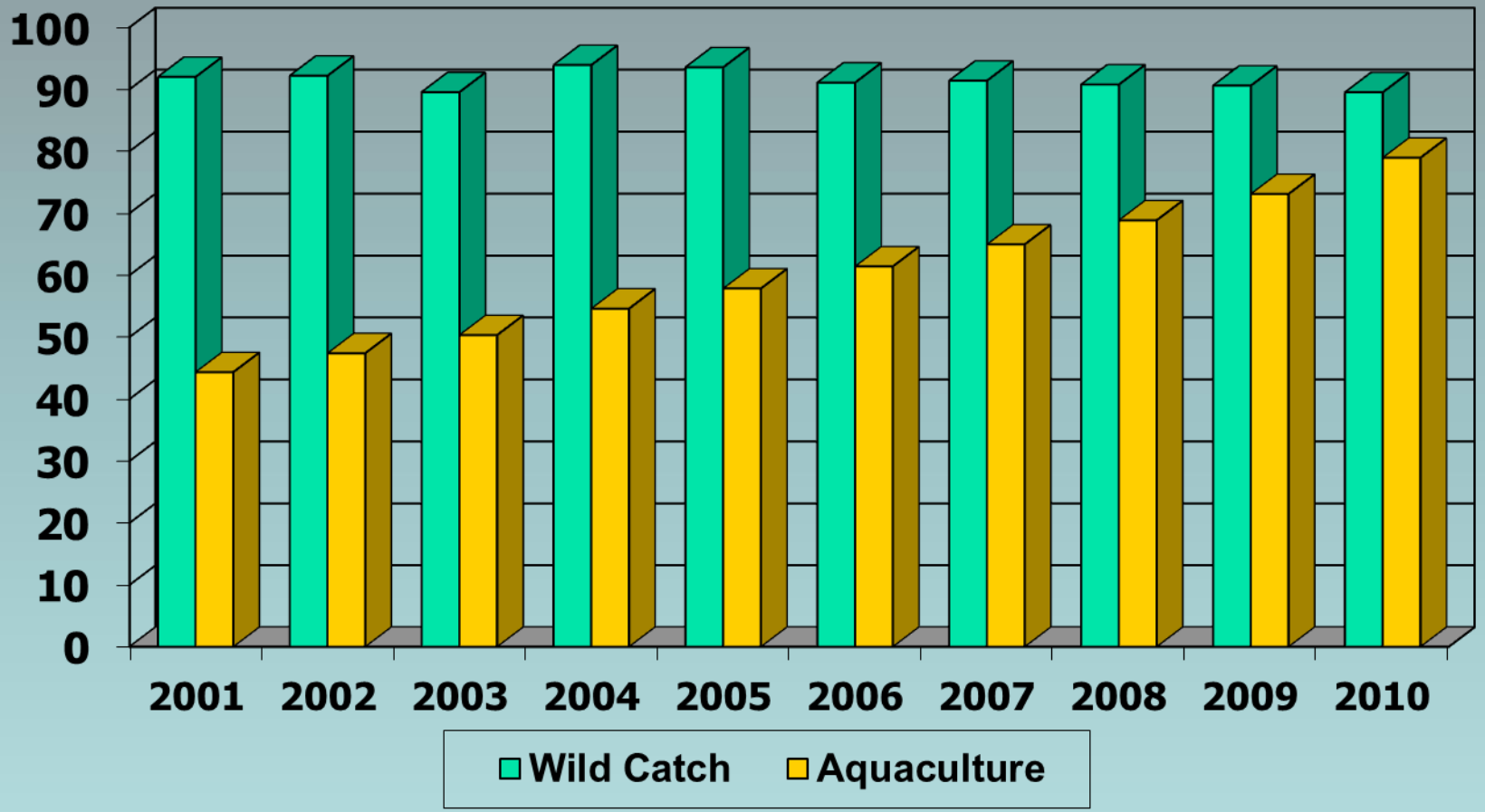
U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Agricultural Research Service
Trout-Grains Project
USDA

Source: FAO Fishstat Plus Version 2.30; Ted Batterson

Total Aquatic Harvest

(Million Metric Tons)



Types Of Species Cultured

- Increased and intensified production of crustaceans, marine finfish and diadromous fishes (Rana et al. 2009)

Increasing Dependence on Prepared Feeds

- In 2008, 46%of total global aquaculture production was dependent of the direct use of feed (FAO 2008)

Balancing Continued Growth And Success

- Aquafeeds are projected to grow at an annual growth rate of 11.7% from 2013 to 2018.
- The continues success of responsible aquaculture and the contribution it makes to global feed security relies of responsibly-sourced feed.

Increased Cost Of Traditional Ingredients

- Since 2006
- Soybean increased by 67%
- Fishmeal increased by 55%
- Corn and wheat, 124 and 130%

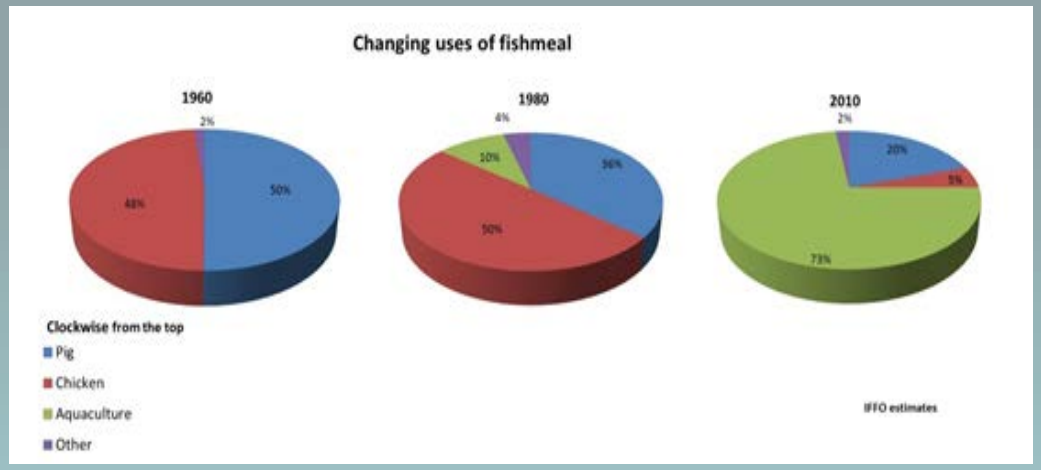
- Oils 250%
- Rana et al. 2009

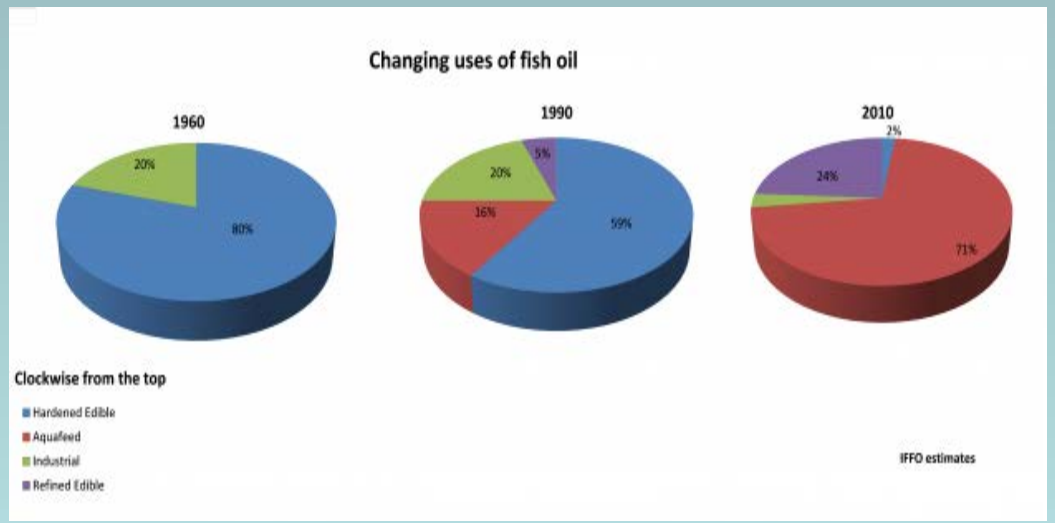
- A Primary Challenge Of Continued Growth Is Feedstuffs
- Sources Of Protein And Lipid Are Needed
  - Cost-effective
  - Maintain growth, health and meat quality

Marine-Harvested Ingredients

- Inconsistencies in prices
- Vulnerability to supply shifts
- Numerous global initiatives to reduce dependence of aquaculture on fishmeal and fish oil

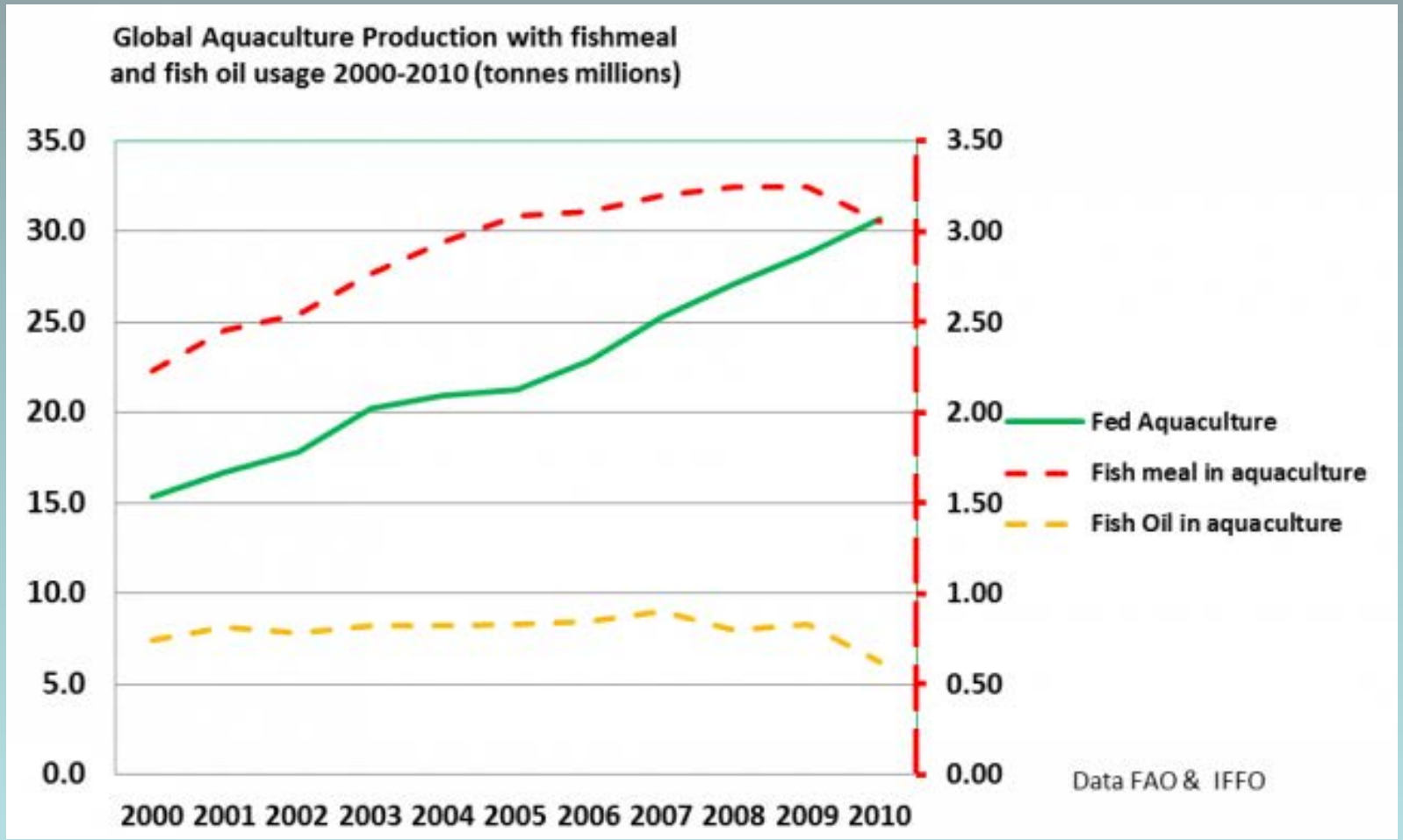
Changing Uses Of Fishmeal And Oil





Aquaculture is important in the context of the usage of fishmeal and fish oil because by 2010 aquaculture was using 73% of global production of fishmeal and 71% of fish oil.

Fishmeal And Fish Oil Consumption In Relation To Growth Of 'Fed' Aquaculture



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

Fishmeal

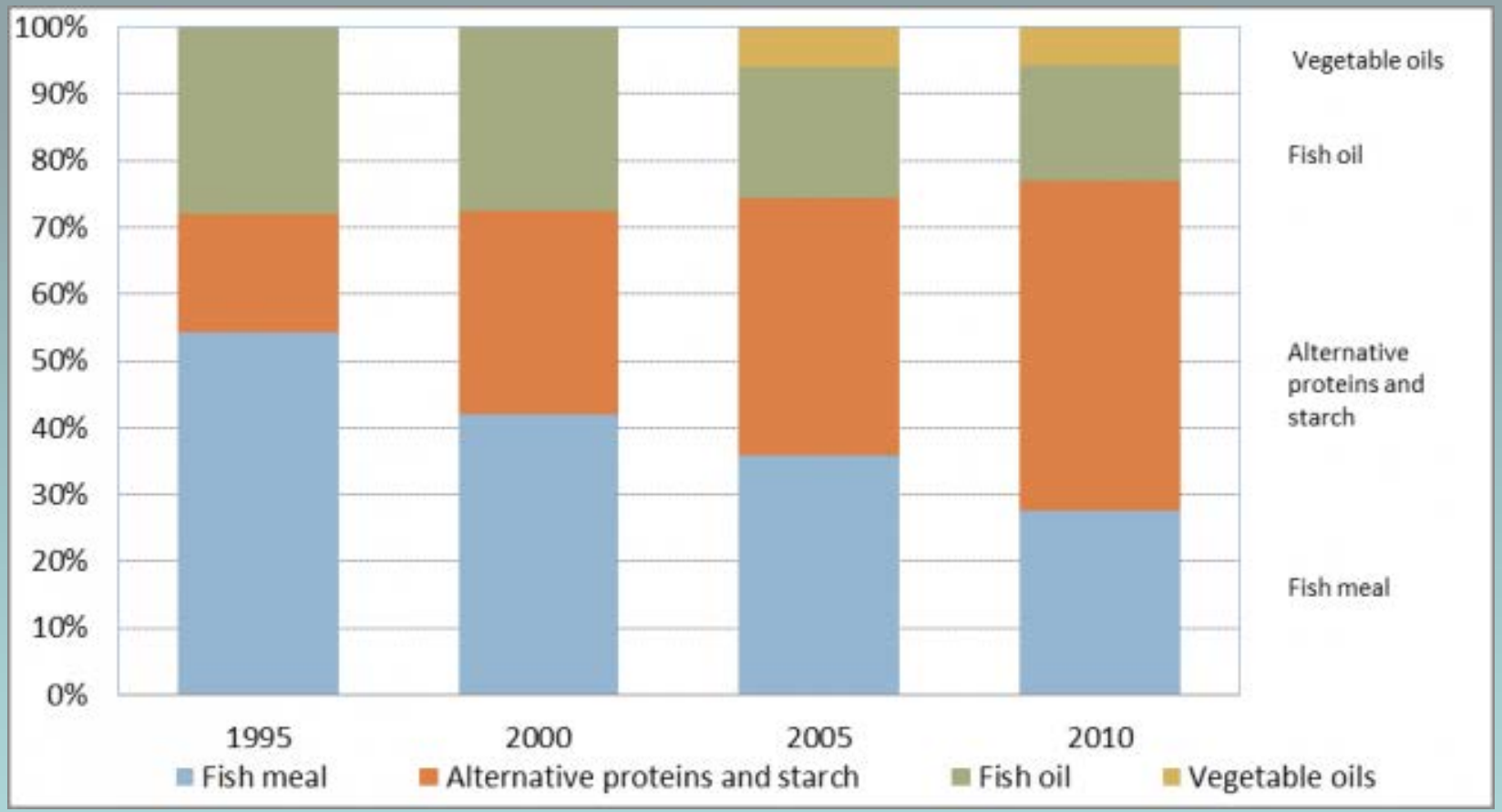
- Marine shrimp 28 to 20%
- Marine fish 50 to 32%
- Salmon 45 to 30%
- Trout 40 to 30%
- Carp 10 to 5%
- Catfish 5 to 10%
- Eel 65 to 55%
- Freshwater crustaceans 25 to 15%

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)

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
121 entries currently
10 to be added soon
10 feeding now

6 for poultry products

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

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

Atlantic salmon
Hybrid bass
Arctic Char
White Sea bass

Experiment 4	Macro-nutrients				Amino Acids																Minerals			
	Dry Matter	Fat	Crude Protein	Energy	Ala	Arg												Thr	Tyr	Val	Sum AA	P	K	S	Zn
Poultry blood meal, 13	78	0	79	73	82	76												69	72	84	80	100	94	23	100
Poultry blood meal, 8521	79	0	77	75	82	83												76	79	80	80	100	93	47	66
Soybean meal, modified, Hamlet HP-300	68	14	90	71	95	97												89	97	93	93	43	95	44	65
Poultry meal, American Dehydrated Foods	100	95	98	99	100	98												100	100	100	100	78	95	66	68
Menhaden fish meal, Special Select	70	82	85	90	91	91	87	97	79	92	95	97	94	99	91	85	94	92	96	94	92	34	90	62	4
Soy protein, bio-fuels coproduct	54	0	91	65	93	98	88	93	83	92	94	96	93	91	82	90	92	89	97	93	92	0	93	35	0
Bacterial Biomass	81	91	89	85	92	96	89	93	90	93	94	94	94	96	84	94	88	92	95	89	92	65	0	45	100
Reference diet #3	76	99	86	83	87	94	83	89	83	88	89	89	89	86	76	88	87	86	91	88	87	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;

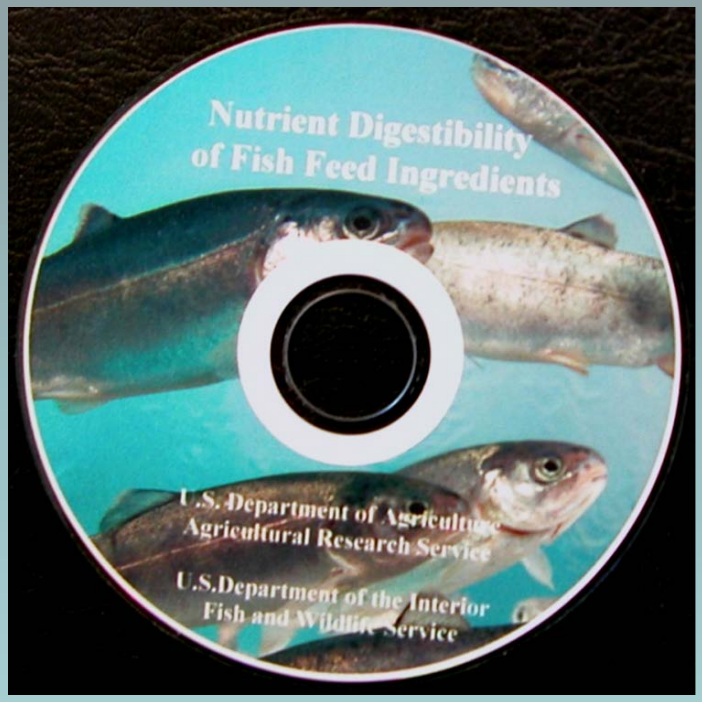
1) **Mini-CD available**

2) **Posted on Web**

Search; ARS Trout-Grains Digestibility

3) **Direct contact; email**

rick.barrows@ars.usda.gov
wendy_sealey@fws.gov



Updates;

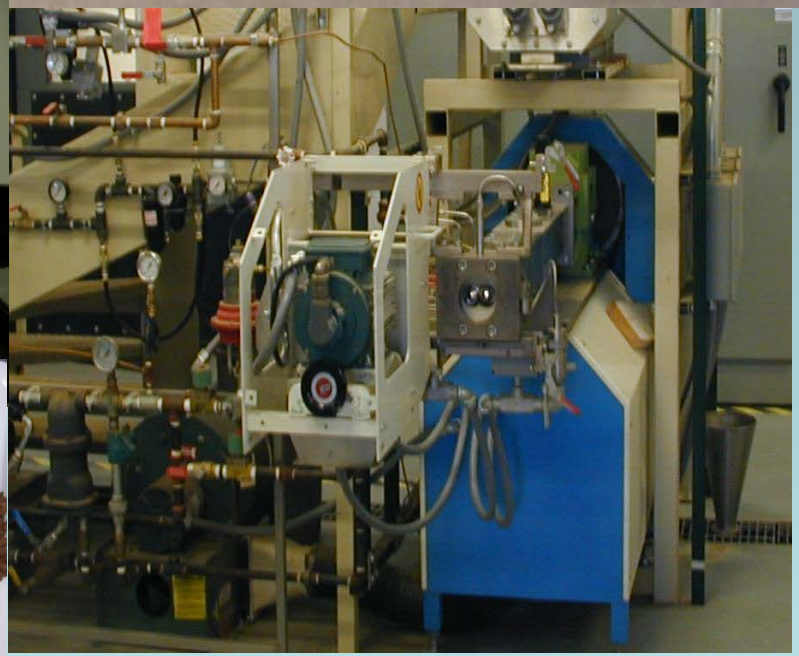
Will be made on web page as soon as new information is available

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.

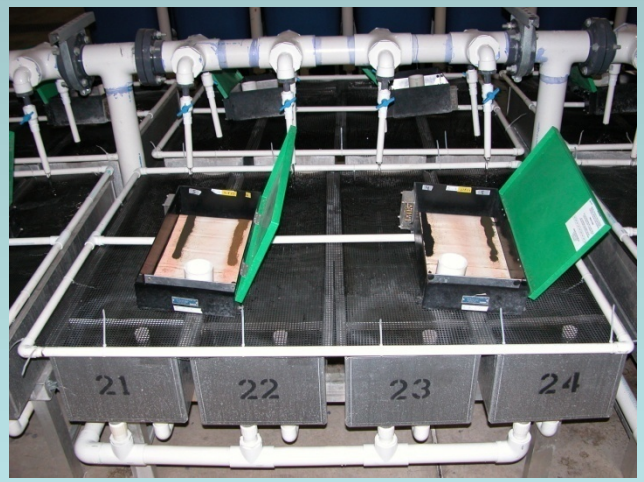
Control diet is 65% high quality sardine meal

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

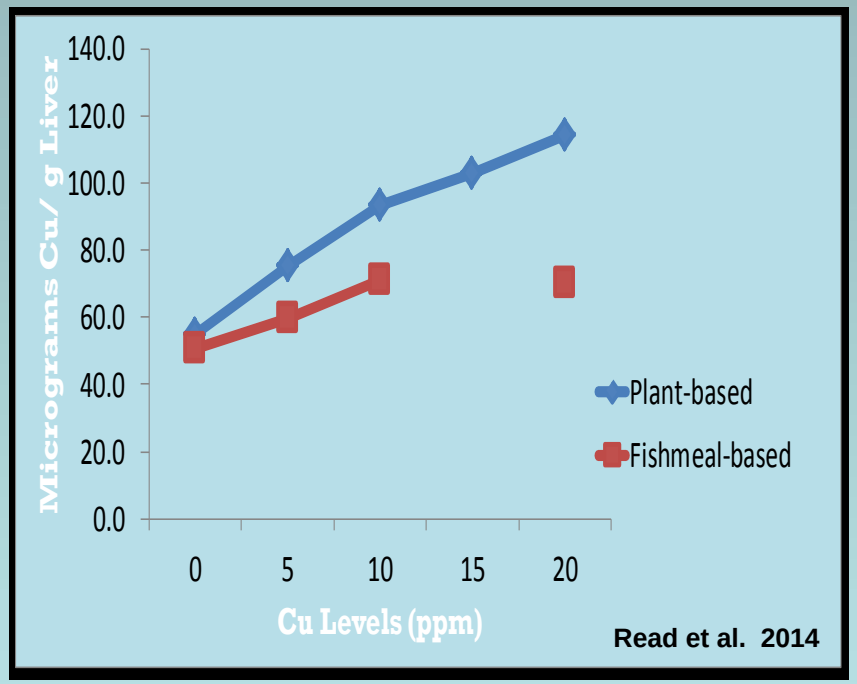


Ingredient Evaluation;
Feeding trials

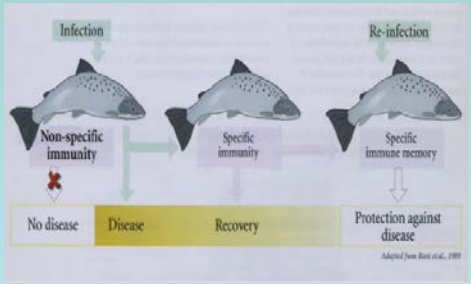
Ingredient Evaluation;
Fish Health

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

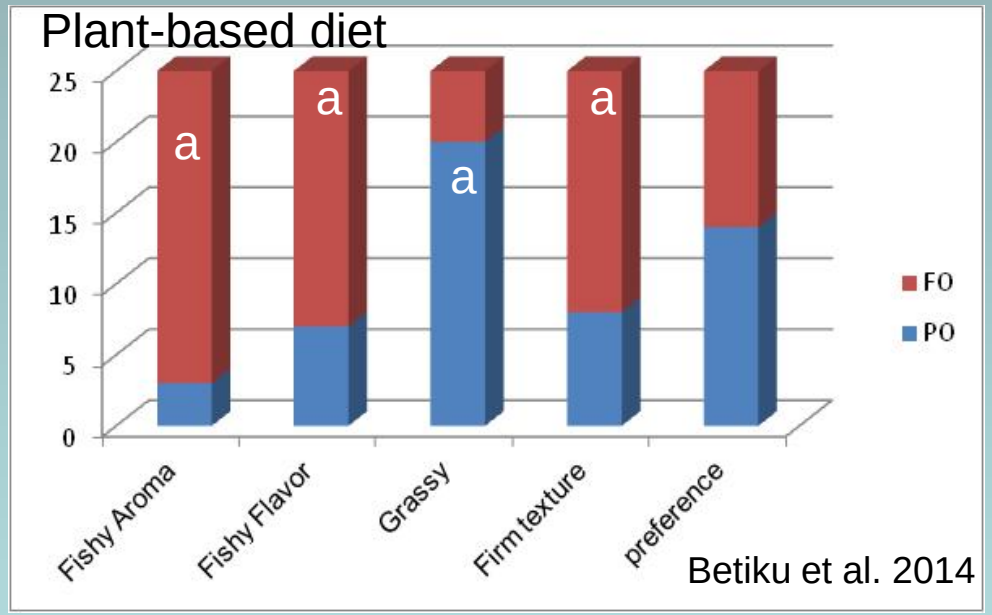


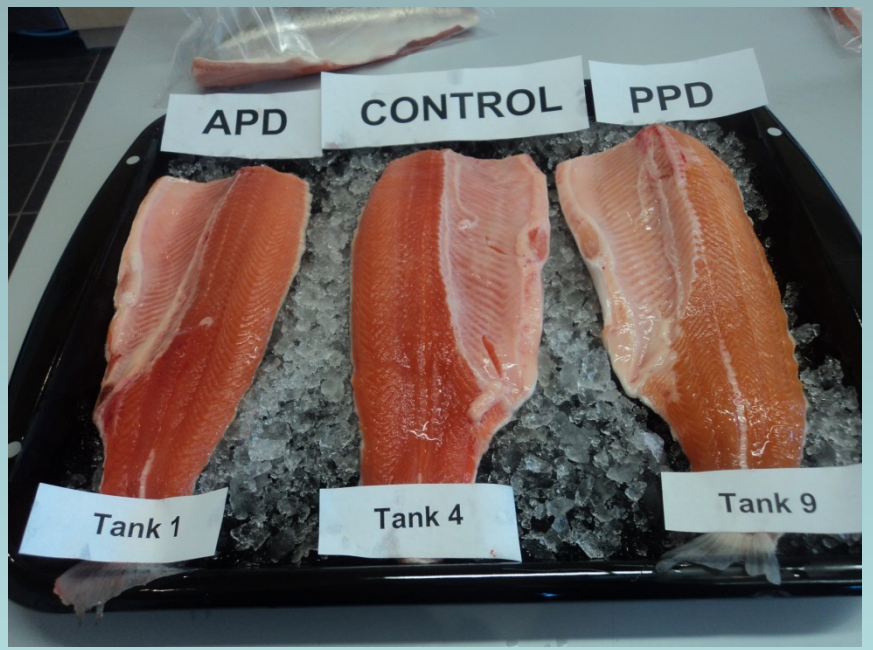
Read et al. 2014



Ingredient Evaluation;
Product Quality

color, flavor, texture
consumer acceptance





Ingredient Evaluation;
Effect on Waste Management

Radial Flow Separators;
30 experimental units

Emerging Sources Of Ingredients

Fuel industry co-products

Fishery processing products

Improved plant products

Nut Products

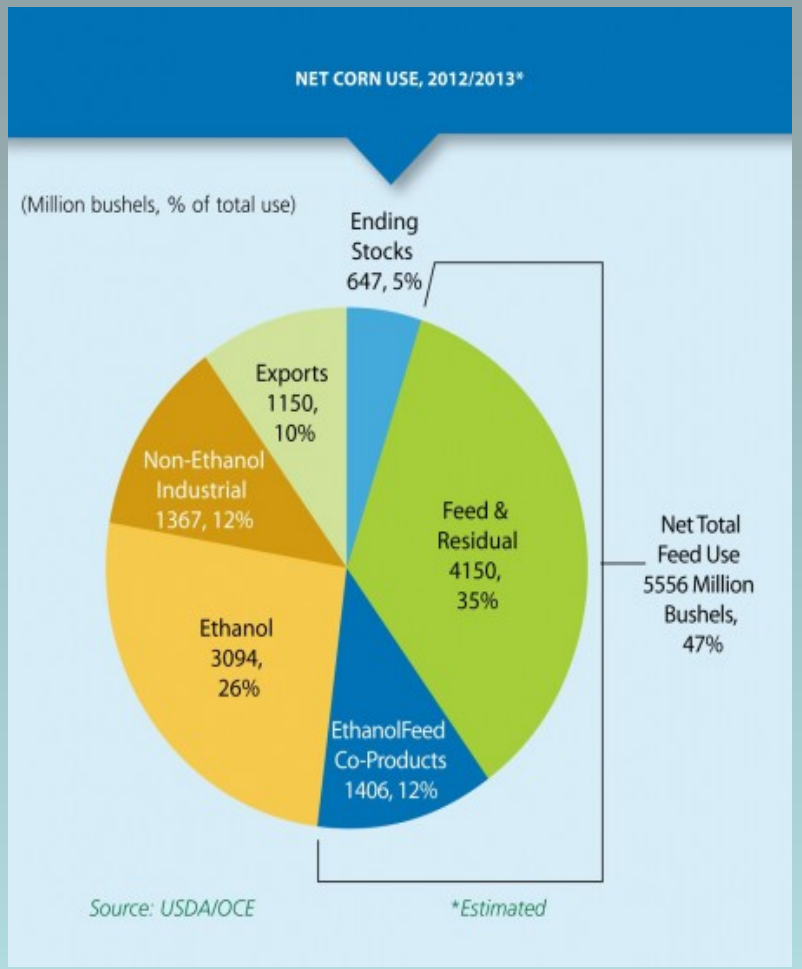
Single cell proteins

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

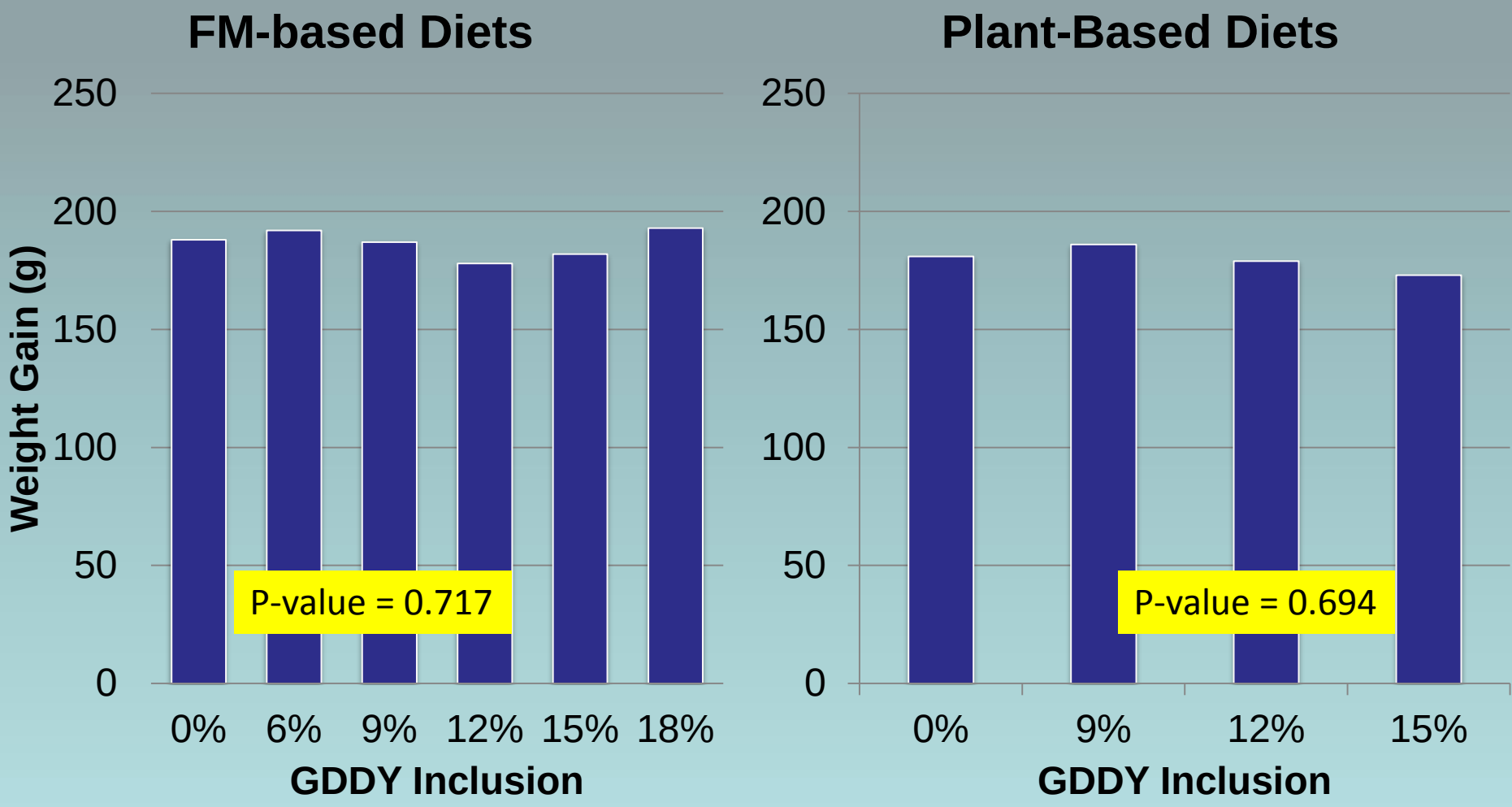
Grain Distiller's Dried Yeast

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

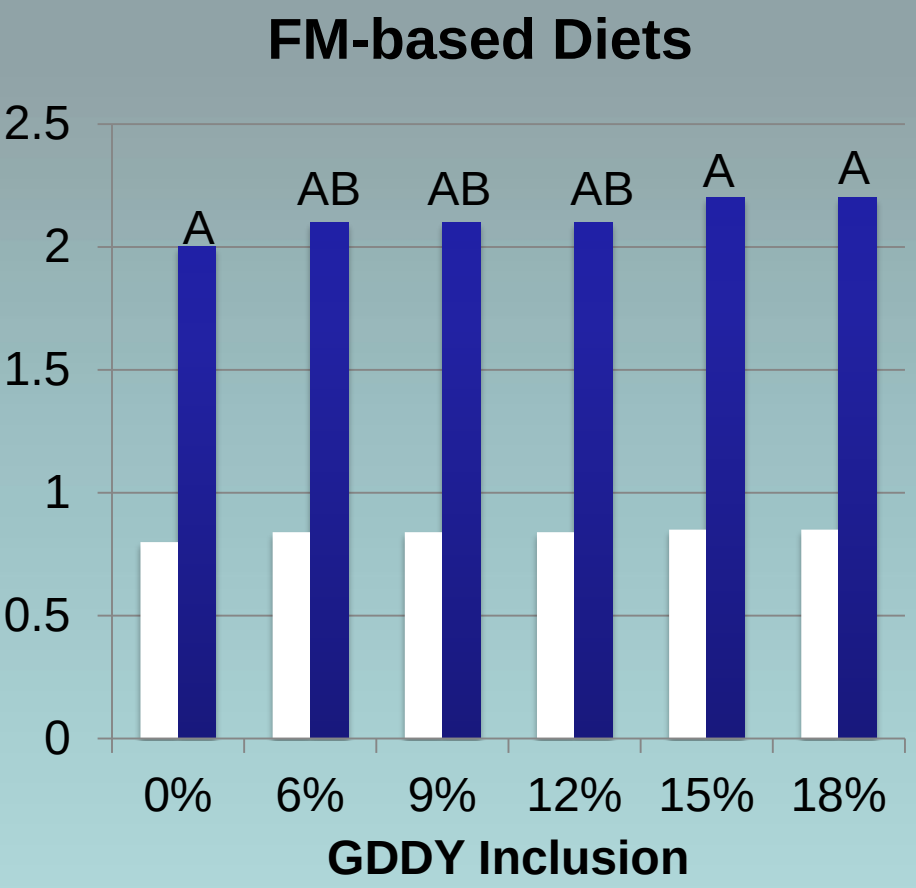
- AACs for Lysine, Methionine, Threonine and Sum of AA were lower than the FM average

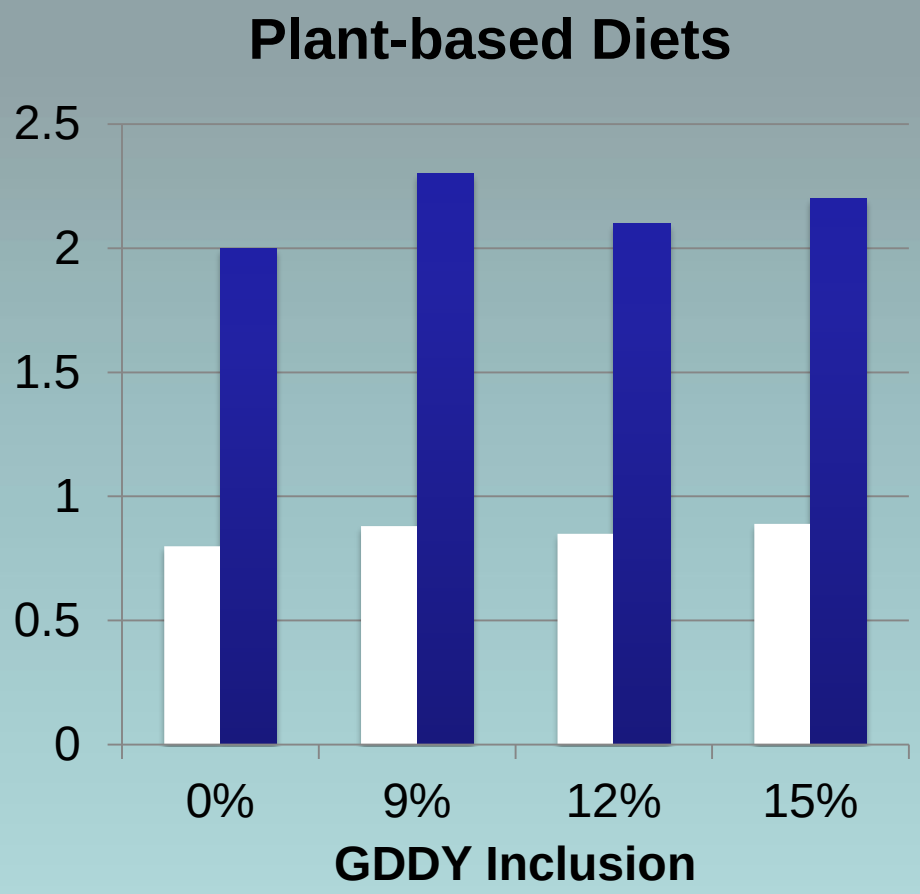
Grain Distiller's Dried Yeast



Sealey et al. 2014a

Grain Distiller's Dried Yeast





Sealey et al. 2014a

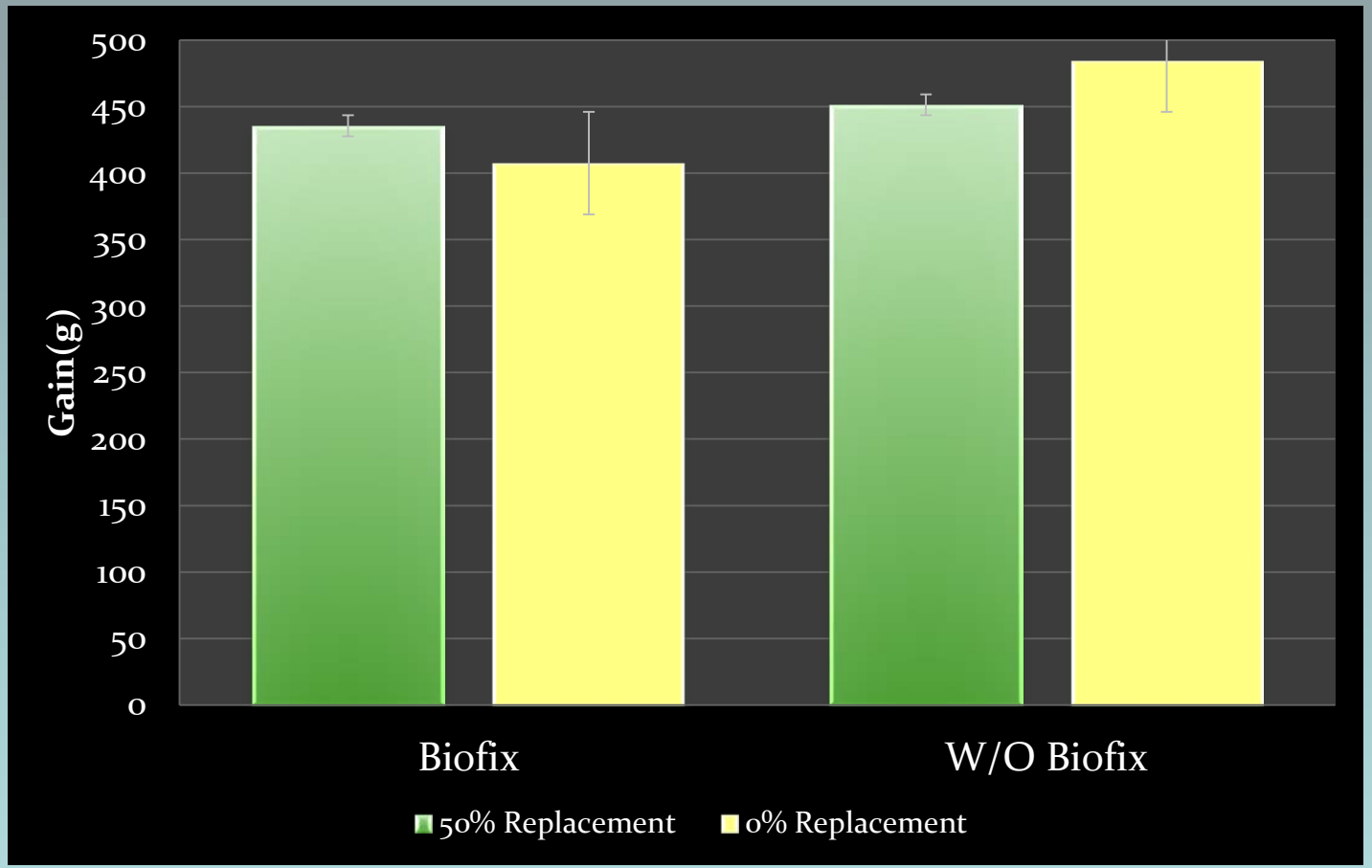
DDGS

	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



Protein: P=0.9130

Supplement = 0.0561

PxS: P=0 .1882

Sealey et al. 2014b

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

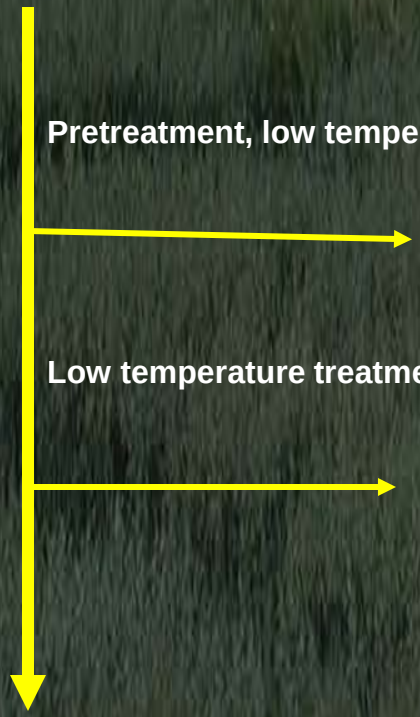
Fish meal A
ULO 3010 A
SPC A
K419 B
204 C
CC C
WF C

No heat treatment

AquaProtein and Ethanol from Barley

Montana Microbial Products; enzymatic method that protects the protein producing some ethanol feed grade or barley not meeting malting standards.

Barley, 12% protein



Pretreatment, low temperature

Barley Protein Conc., ~41% protein

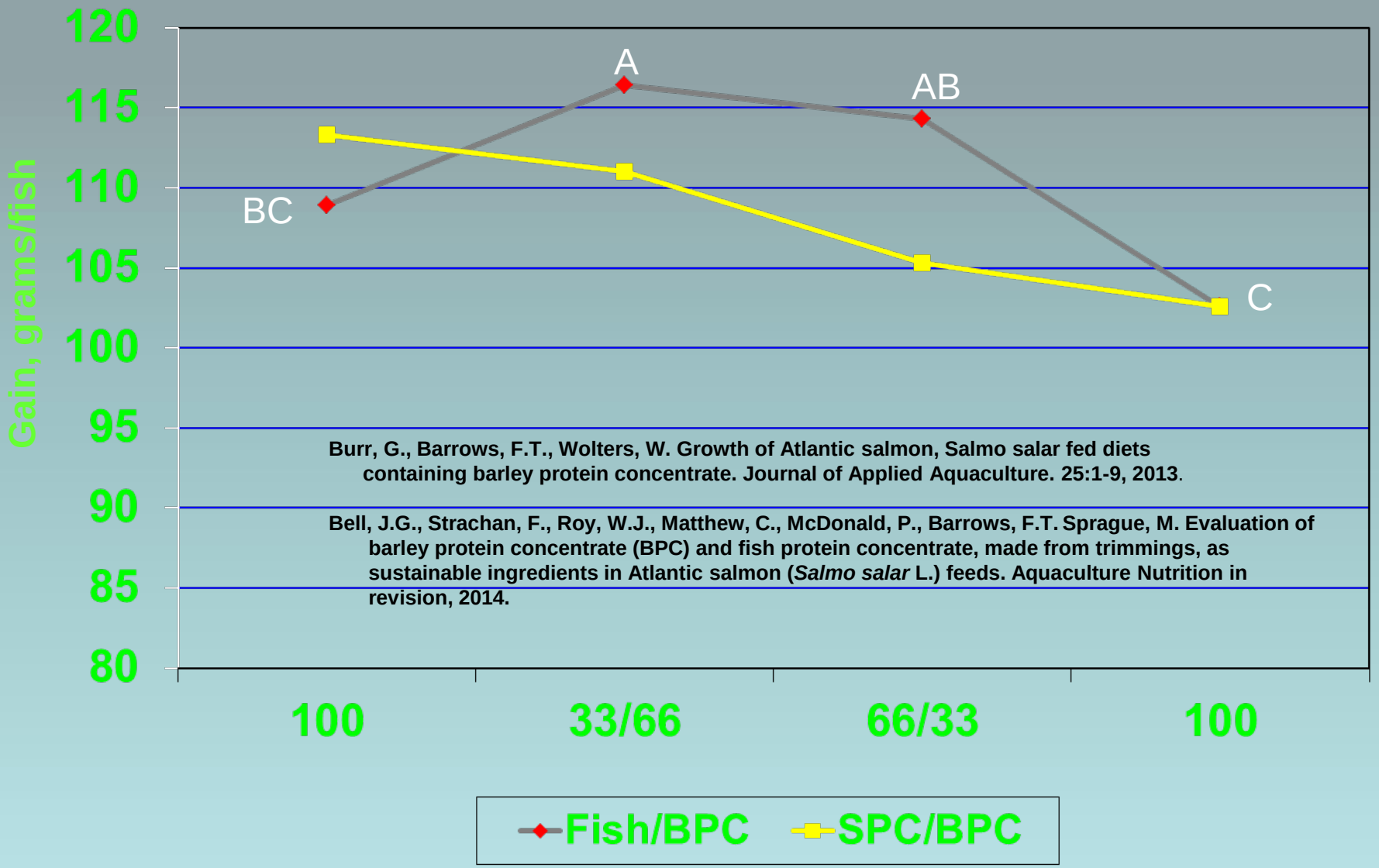
Low temperature treatment

Barley Protein Conc., ~49-55% protein

Ethanol

460% protein concentration

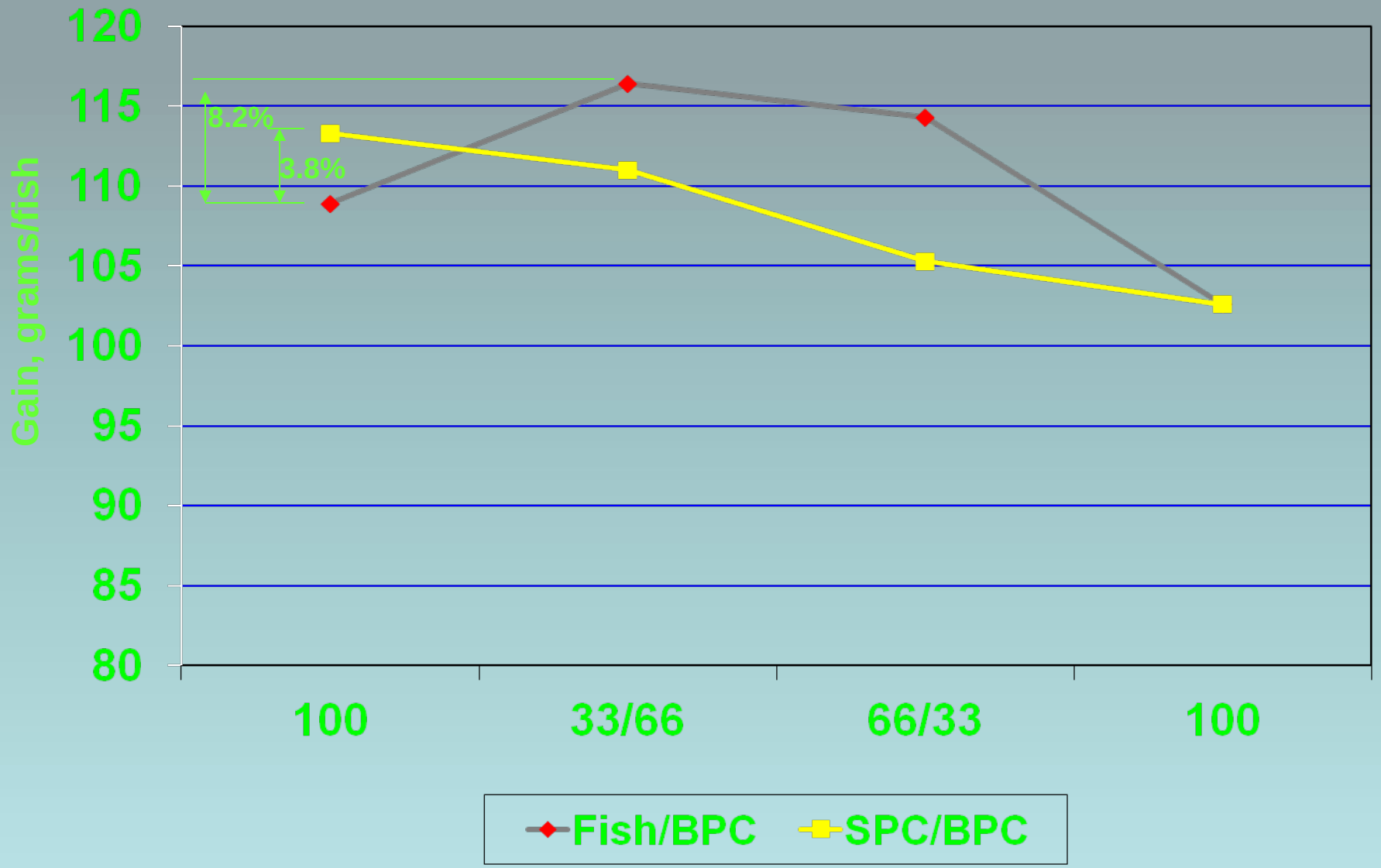
Substitution of fish meal or soy protein concentrate with barley protein concentrate; 9 weeks



Burr, G., Barrows, F.T., Wolters, W. Growth of Atlantic salmon, Salmo salar fed diets containing barley protein concentrate. Journal of Applied Aquaculture. 25:1-9, 2013.

Bell, J.G., Strachan, F., Roy, W.J., Matthew, C., McDonald, P., Barrows, F.T. Sprague, M. Evaluation of barley protein concentrate (BPC) and fish protein concentrate, made from trimmings, as sustainable ingredients in Atlantic salmon (*Salmo salar* L.) feeds. Aquaculture Nutrition in revision, 2014.

Substitution of fish meal or soy protein concentrate with barley protein concentrate; 9 weeks, ongoing



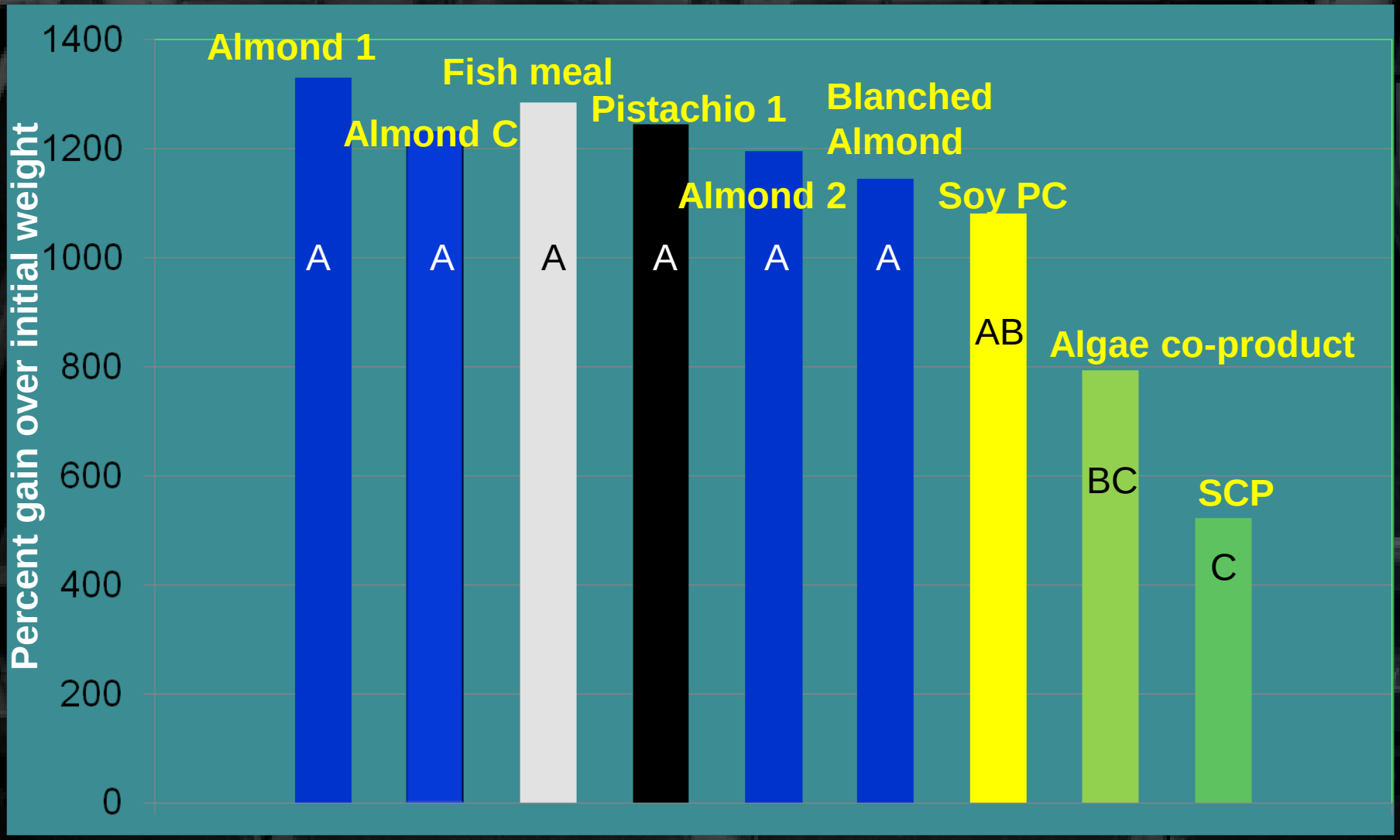
- Pistachio, walnut and almond industries are primarily whole nut markets, and some are off size or color or broken and can not be certified for human consumption.

- California alone produced over 2,000,000 tons of nuts in 2010. If drought doesn't tighten, the number of groves bearing fruit will increase by 45% in 5 years

- Nutrient profile of processing waste is not good for aquafeeds.

Adaptive Bio-Resources, Llc
high-value agricultural products

First Feeding Fry Screening



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

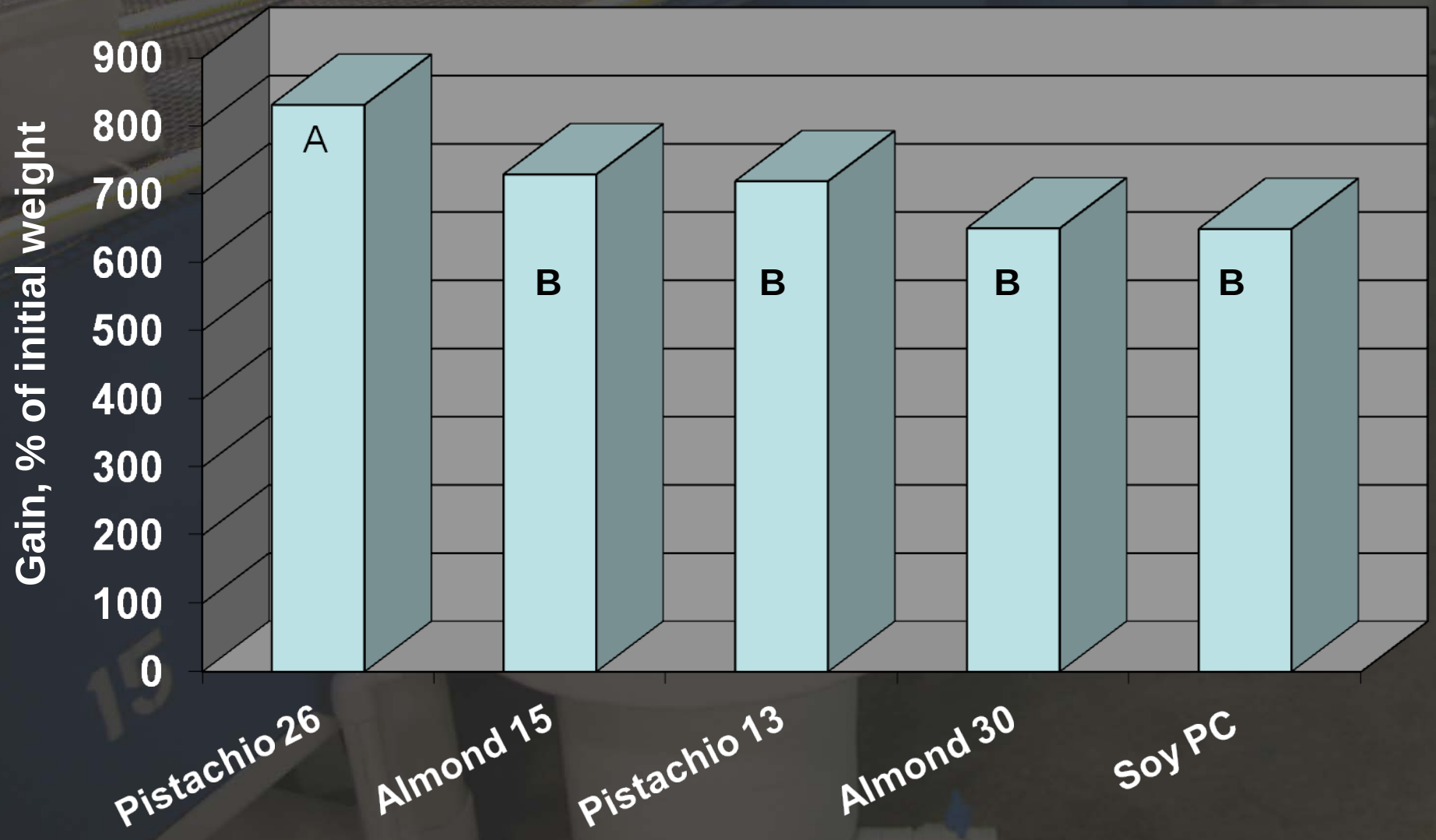
	Macro-nutrients			
	Dry Matter	Fat	Crude Protein	Energy
Fish meal, Menhaden, Special Select™, Omega Proteins	71	92	83	88
Blanched Almond meal, Adaptive Bio-Resources	59	90	92	76
Almond meal, Adaptive Bio-Resources	57	92	92	72
Pistachio meal, Adaptive Bio-Resources	64	96	86	75
Almond Meal, first cut, Adaptive Bio-Resources	59	100	90	70
Almond Meal, second cut, Adaptive Bio-Resources	61	98	87	69
Soy Protein Concentrate, Profine VF, Solae	72	75	94	81

12 week fingerling study

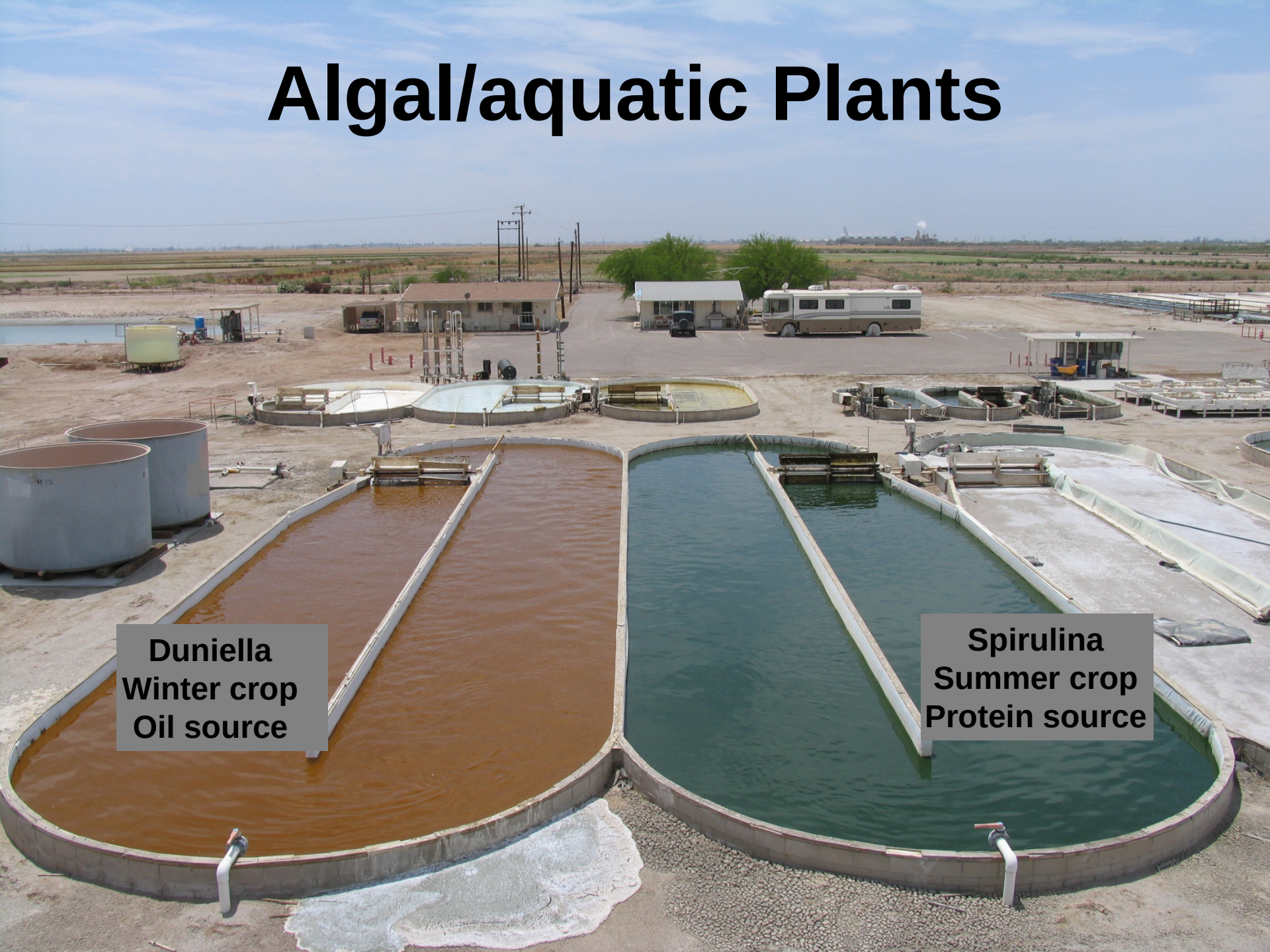
Plant-based Feeds
Soy Protein Conc. Replacement Series

	Soy	Almond		Pistachio	
	control	15	30	13	26
Soy Protein Conc.	20.0	10.0	0.0	10.0	0.0
Almond meal	0.0	14.99	29.98	0.0	0.0
Pistachio meal	0.0	0.0	0.0	13.37	26.74
Corn protein conc.	*26.33*	*26.33*	*26.33*	*26.33*	*26.33*
Wheat flour	24.81	20.21	15.66	22.61	19.02
Fish oil	19.39	18.40	17.40	17.30	17.40
Others, aminos, vita. etc	9.45	10.71	12.54	10.39	10.51

Effect of replacing Soy Protein Concentrate with either Almond or Pistachio meal on weight gain of rainbow trout



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

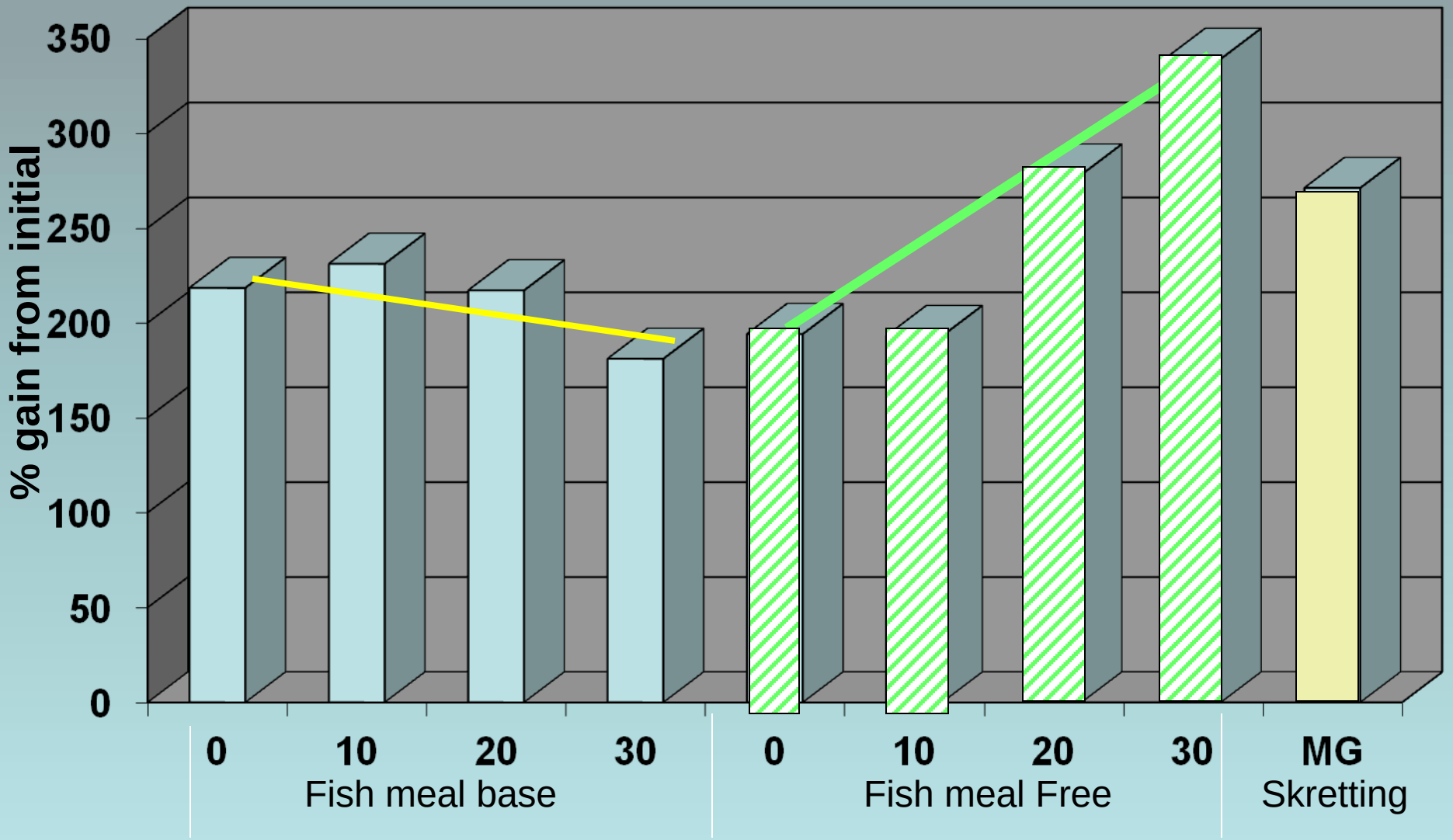
3) **Functionality;** dramatic expansion, increased pellet durability
increased oil absorption capacity

4) **Growth trials**

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

Effect of base formula and added spirulina meal on growth of white sea bass; 8 weeks

Hubb's Sea World Research Institute



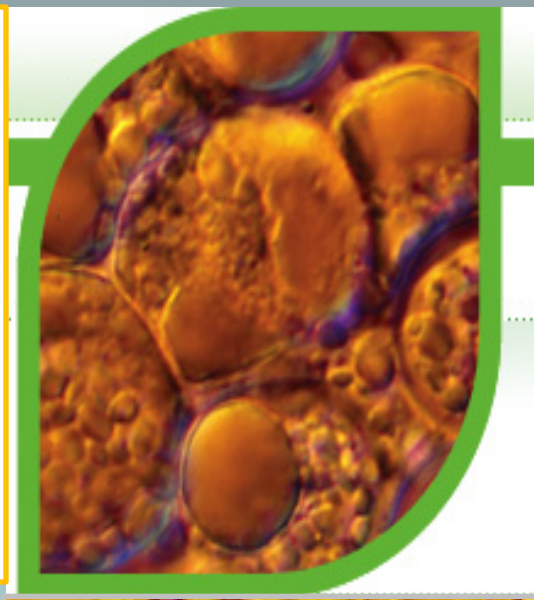
DHA-Gold

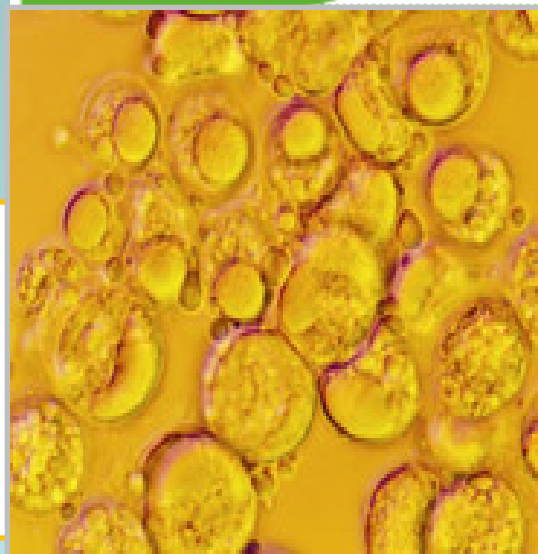
DHA-GOLD:

- 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)



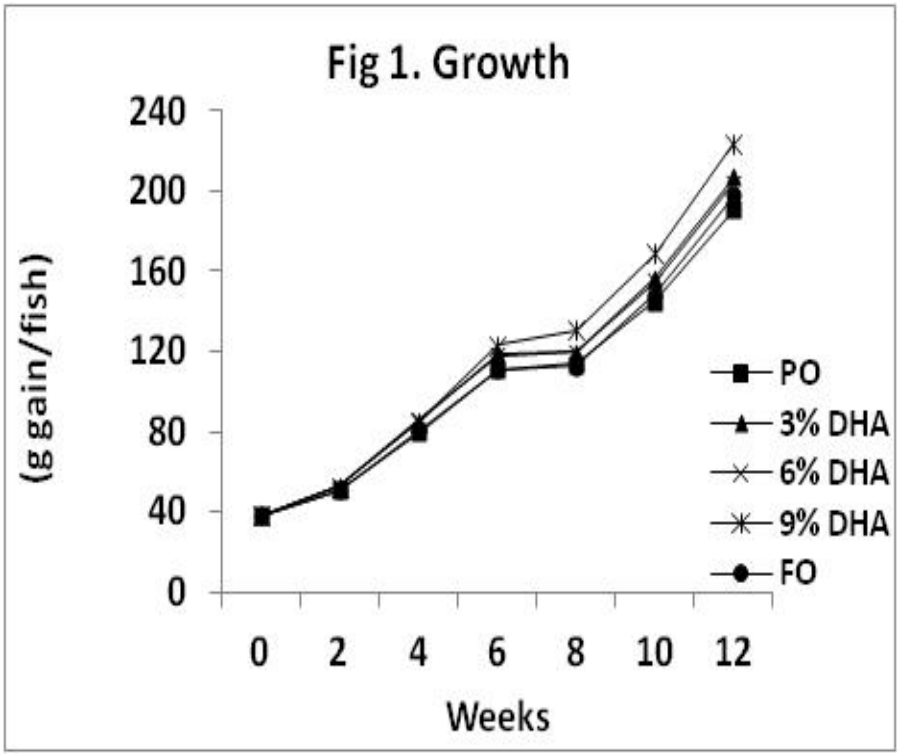


This Study:

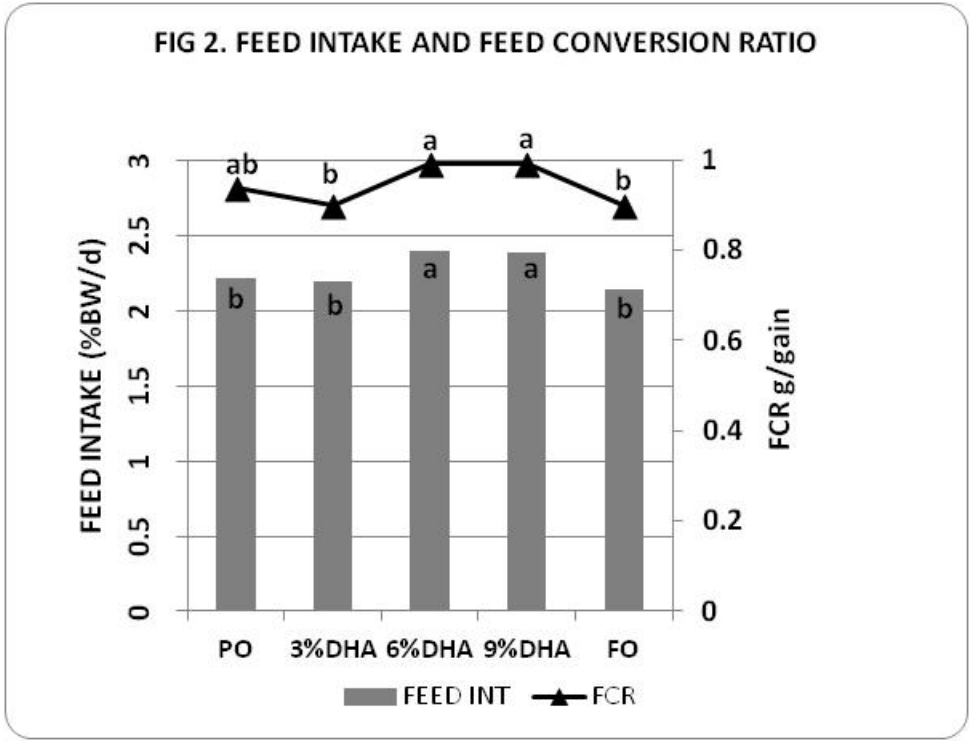
Investigated the fillet fatty acid profile, texture, sensory analysis, and growth performance of rainbow trout fed experimental diets with DHA-Gold as a replacement for fish oil

DHA-Gold

Growth of rainbow trout during 12 Weeks feeding experiment

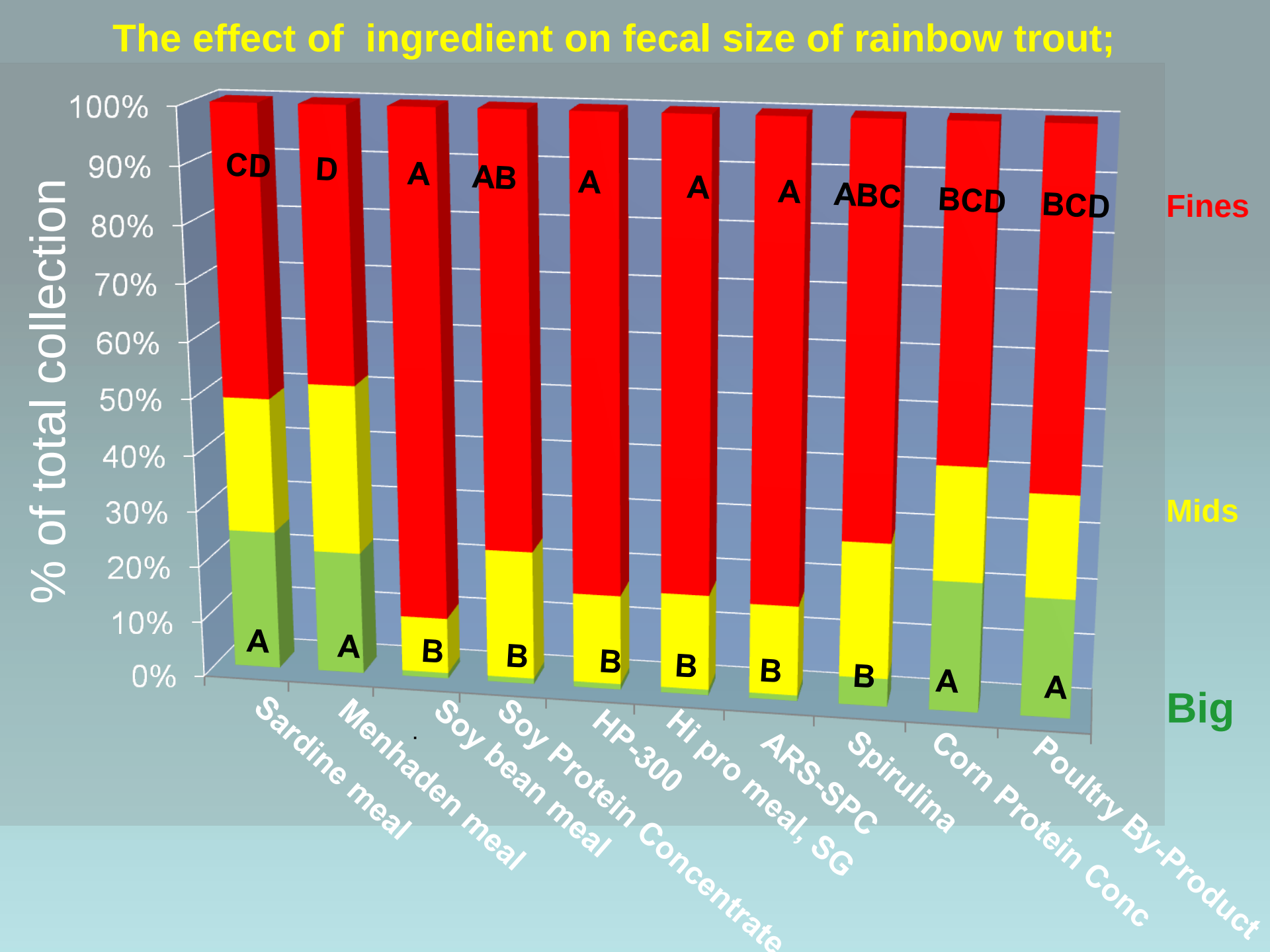


Feed intake of rainbow trout 12 Weeks feeding experiment



Betiku et al. 2014

The effect of ingredient on fecal size of rainbow trout;



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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- U of I Extension Staff

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