

Advances in Alternative Aquafeeds

for

Aquaculture Innovation Workshop
January 17-18, 2011



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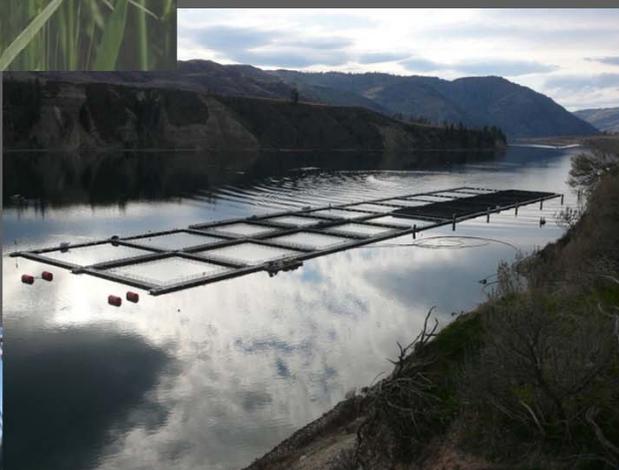




Alternative Aquafeeds

ARS Feed Development

Bozeman Fish Technology Center, Montana



Aquaculture Innovation Workshop **Advances in Alternative Aquafeeds**

Today

- 1) Where we are and how we got here
 - a) Ingredient evaluation
 - b) Ingredient development
 - c) **Supplementation/requirements (w/o fish meal)**

 - 2) What is ahead; ingredients and complete feeds.
Feeds for Re-circulating Aquaculture Systems
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Where we are

ARS Fish Meal Free Aquafeeds



Gateway or Demonstration Formulas

Trout

Salmon

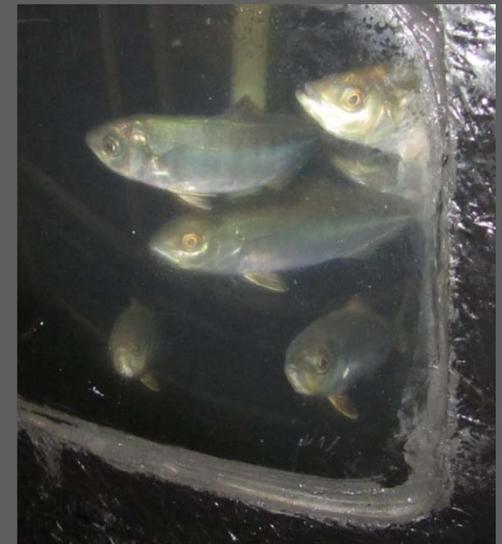
Arctic char

Cobia

White Sea bass

Yellowtail

Matched or surpassed the fish meal control and/or commercial reference diet



Advances in Alternative Aquafeeds

Aquaculture Innovation Workshop



How we got there

Approach

- 1) **Ingredient evaluation; *process***
- 2) **Ingredient development; *4 approaches***
- 3) **Nutrient requirement/supplementation.**
- 4) **Complete feed evaluation; *multiple stages***

Ingredient Evaluation



1) Compositional analysis

- Nutrients; protein, energy, amino acids, fatty acids, etc.
- Anti-nutrients; evolved in a protective or developmental role

2) Palatability; Effect on feed intake

3) Digestibility; Apparent Digestibility Coefficients

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

5) Growth; gain, FCR, fecal prod. product quality



Anti-nutrients in plant derived ingredients

Soybean Meal;

Glycinine, ug/kg

Beta Con Glycinine, ug/kg

Lectins, mg/kg

Dry solids, g/kg

Stachyose, g/kg

Raffinose, g/kg

Oligosaccharides, g/kg

Trypsin Inhibitor Activity, mg/g

Saponin, Type B Ba, g/kg

Saponin, Type Bb' (type I), g/kg

Saponin, Type Bb (type I), g/kg

Saponin, Type B Bc (type II, III), g/kg

Saponin, Type B Bc' (type II, III), g/kg

Type B Saponins, g/kg

Type DDMP Saponins, g/kg

Total Type B and DDMP Saponins, g/kg

Phytate

Barley:

Phytate

Glucosinolates

Alkaloyds



2&3) Palatability and Digestibility

Apparent Digestibility Coefficient, %

Ingredients

Select menhaden fish meal
Peruvian Anchovy
Sardine
Mexican fish meal
Menhaden FAQ
Poultry by-product, pet food
Blood meal, SD poultry
Feather meal
Soybean meal
Corn gluten meal
Canola meal
Whole wheat
Wheat mill run
Whole corn
Wheat flour
Cottonseed meal
Wheat midds
Rice bran
Rice protein conc., 70%
Soy protein concentrate
Barley protein conc., 25%
Wheat gluten meal
Whole flax

Waxbar barley
CSM Batch 2
Soybean meal, in-situ esterfied
Soybean meal, bio-diesel control
Barley Protein Concentrate, 1 step
Barley Protein Concentrate, 2 step
Barley Protein Concentrate, pilot
Fisheries by-product, NOAA 1
Fisheries by-product, NOAA 2
Oberon, bacterial protein
Maggot purree
Pepsinogen, soy-fungal
Annelids
Black soldier fly larvae
Nu-Pro, yeast protein
Bio-fuel algal mass S-1
Bio-fuel algal mass T-6b
Bio-fuel algal mass M-3
Bio-fuel algal mass D
Phosphorus chelate
Phosphorus proteinate

Nutrients

Poultry by-product

Dry matter	83.7
Protein	84.7
Energy	89.9
Ash	44.2
Organic matter	89.0
Asp	80.3
Glu	87.7
Ser	87.1
His	87.6
Gly	85.4
Thr	84.7
Ala	89.7
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



- Basal formula
- Inclusion rates
- Feed processing
- Fish size
- Water temperature
- Fecal collection
- Time of collection
-

ADC's for Trout Trials in 2010



	DM	Fat	Protein
Soybean Meal 48%CP	75.3	85.8	95.9
Soy Protein Concentrate	94.3	187.3	103.1
Barley Protein Concentrate	97.3	102.9	99.7
Corn Protein Concentrate	95.0	91.7	89.5
Spirulina, CCC	77.5	85.4	80.5
Spirulina, Earthrise	83.9	69.7	80.3
Menhaden Special Select	98.3	101.9	91.7
Krill Meal	85.0	99.1	84.4
Yeast protein, NuPro	19.9	5.8	36.7
Reference diet	76.3	98.3	86.6
<hr/>			
Poultry Blood 8521	79.1	-13.9	76.9
Modified Soy, Hamlet	67.5	13.8	90.3
Chicken meal, ADF	100.3	94.8	98.3
Menhaden Special Select	70.1	81.7	85.2
Modified Soy Omnitek	54.1	-5.7	90.9
Bacterial Biomass, ADM	81.2	91.0	89.4
Reference diet	76.3	98.7	86.1
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Menhaden Special Select	79.2	89.1	91.1
HPDDG DDGS	51.5	78.6	83.0
Wentworth DDGS	50.4	79.1	87.6
Valero DDGS	39.7	83.2	80.8
Eliot SBM lot A	61.3	36.8	90.8
Eliot SBM lot B	57.1	45.5	85.7
Eliot SBM Sample C	69.9	111.0	95.5
SBM (Standard ADM 47%)	29.5	76.0	77.1
Selecta SPC Solae	53.2	70.4	90.4
Reference diet	75.9	94.9	83.4

	DM	Fat	Protein
Menhaden, Special Select	84.6	112.4	84.9
ARS Protein co-product	70.9	119.1	83.3
ARS Mineral Supplement	79.7	107.3	79.0
FD Algae, unknown	36.3	-22.4	20.8
Worms	71.4	71.5	74.3
Reference diet	63.7	90.3	87.3
<hr/>			
Menhaden Select	76.8	102.4	82.3
Canola Protein Conc.	69.4	111.6	81.1
Corn Protein	80.0	108.0	74.5
Nu-pro	41.8	109.6	54.9
NOAA	85.6	101.7	84.8
Spirulina	90.9	139.3	84.6
Barley Pro.	73.1	90.1	91.2
Reference diet	71.2	93.8	86.2



Apparent Digestibility Coefficients

National Center for Coldwater Marine Aquaculture

Arctic charr

Atlantic Salmon

Ingredient	OM	DM	Protein	OM	DM	Protein
Spirulina, CCC	80.1	77.9	82.2	85.5	82.1	84.6
Corn Gluten Meal	73.8	67.2	84.6	88.4	86.4	94.1
Soybean Meal	54.9	44.9	77.2	80.2	69.6	93.7
Soy Protein Conc.	38.9	32.0	79.0	77.1	65.5	90.7
P > F value	0.01	0.001	0.09	0.09	0.02	0.03

Hybrid Striped Bass, Pompano, Cobia

Ingredient Evaluation

4) Functionality Testing



Ingredient Evaluation

5) Growth Trials

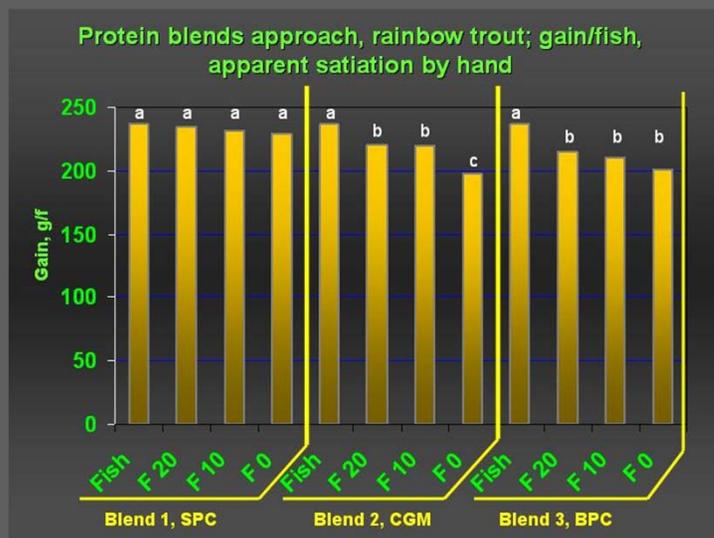
1) Laboratory scale

- a) single ingredient replacement
- b) protein blend approach

2) Pilot Scale; practical formulations

Sensory evaluation of final product

3) Third Party Validation; reference diet



Growth Trials; Single Ingredient Replacement

Substitution of fish meal or soy protein concentrate with barley protein concentrate or Bio-soy

	F 100	F66/BP33	F33/BP66	BP100
Fish meal	34.25	22.84	11.42	--
Soy Protein Conc.	--	--	--	---
Barley Protein Conc.	--	14.75	29.50	44.11
Fish oil	12.60	13.85	15.05	16.15
Flour	31.68	23.80	17.34	11.33
Poultry by-product meal	9.82	9.82	9.82	9.82
Blood meal	6.33	6.33	6.33	6.33
Soybean meal	3.42	3.42	3.42	3.42

SP100

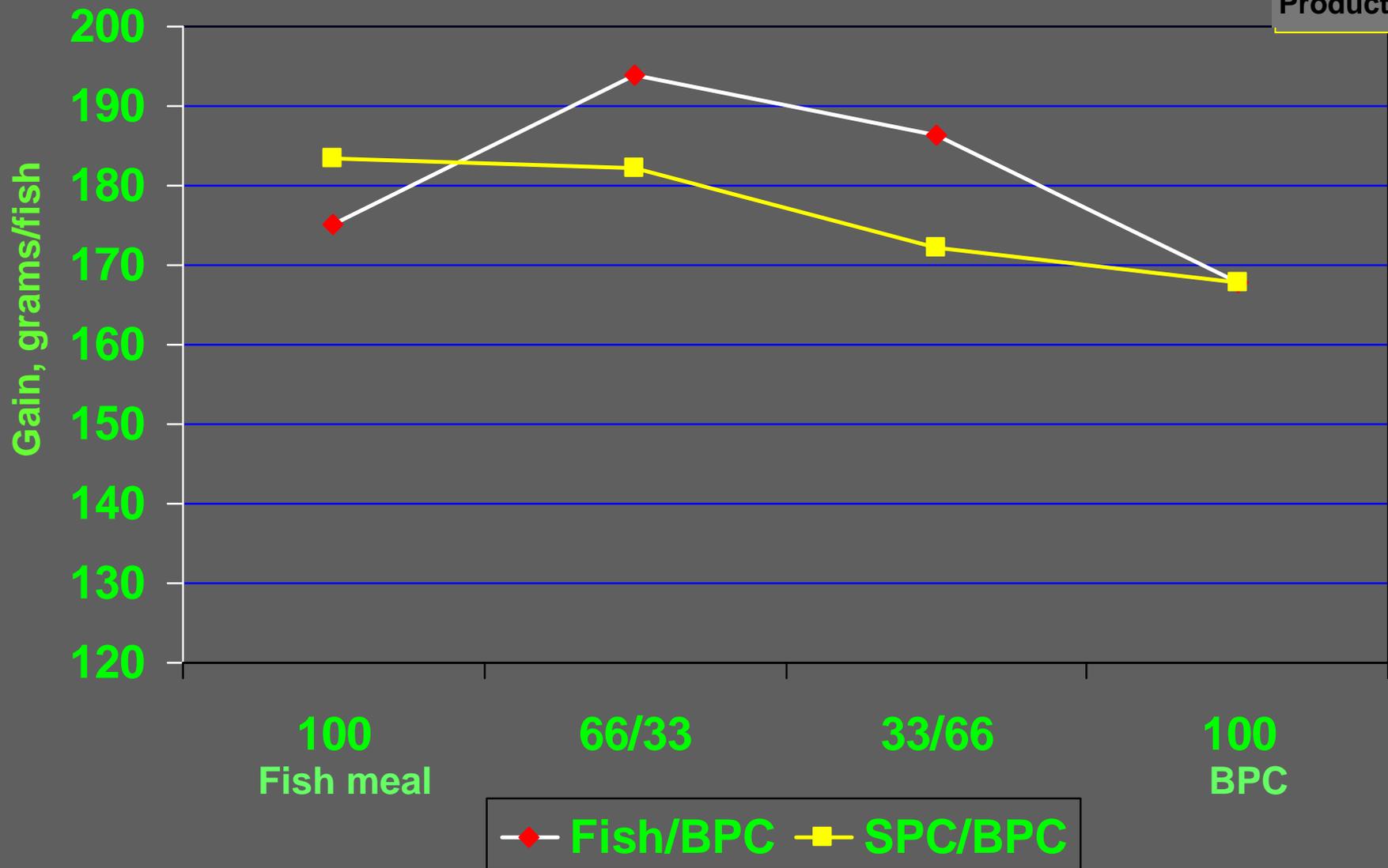
SP66/BP33

SP33/BP66

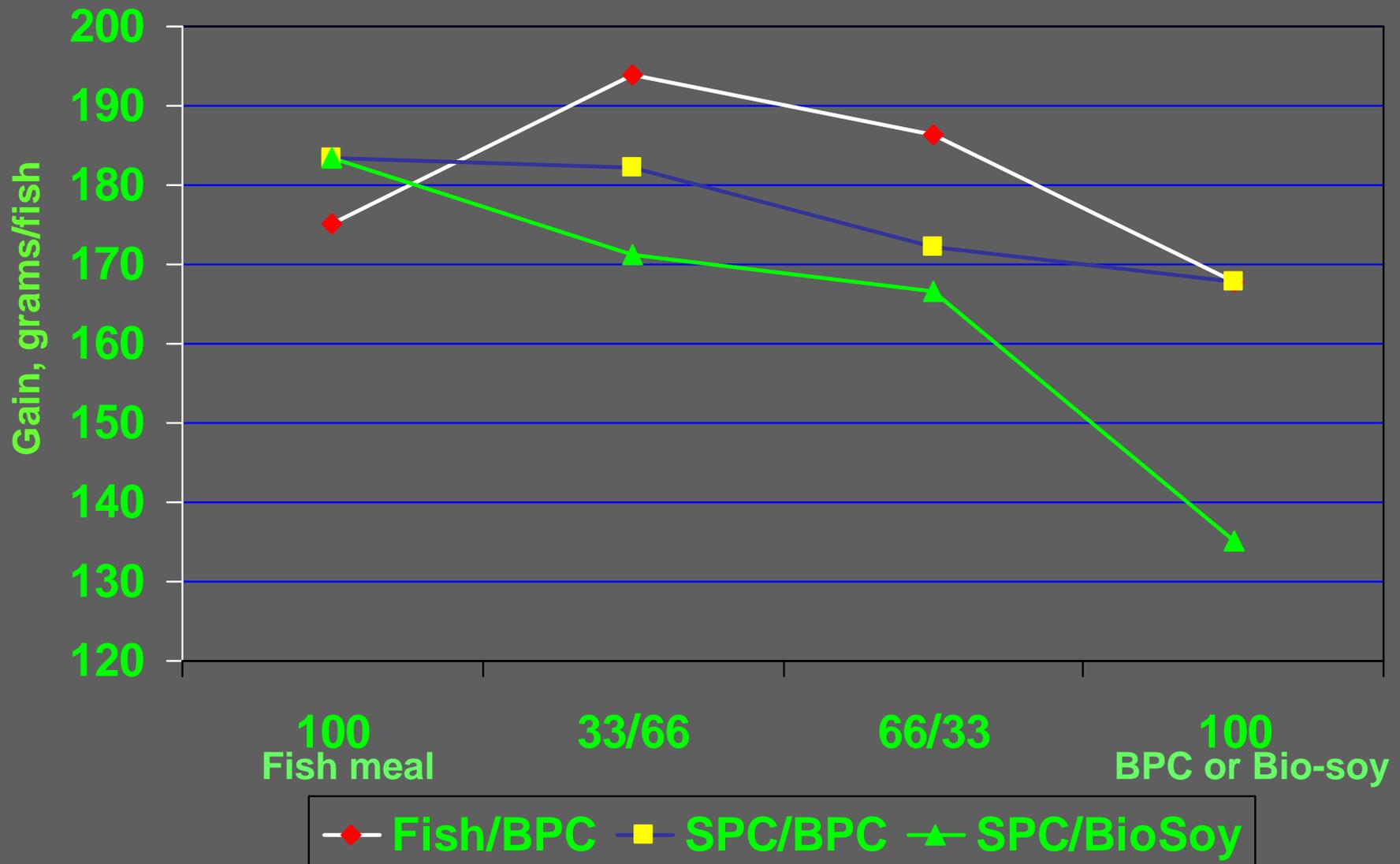
BP100

Substitution of fish meal or soy protein concentrate with barley protein concentrate; 12 weeks

Montana
Microbial
Products



Substitution of fish meal or soy protein concentrate with barley protein concentrate or Bio-soy; 12 weeks





Third Party Validations

feed produced commercially

Freshwater Institute
Clear Springs Foods
Virginia Trout and Salmon
American Trout and Salmon

All diets formulated on an available amino acid basis to target protein profile



Ingredient Development for Aquaculture Feeds

In-house and Extramural

- 1) Chemical
- 2) Mechanical
- 3) Biological
- 4) Genetic



Ingredient Development for Aquaculture Feeds

1) Chemical Modification

ARS patent; licensed to Montana Microbial Products, LLC

Barley, 12% protein

Pretreatment, low temperature

Barley Protein Conc., ~41% protein

Low temperature treatment, fermentation, no distillation

Ethanol

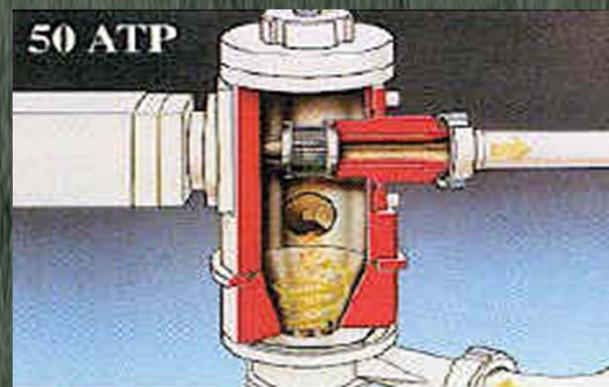
Barley Protein Conc.,
~55% protein

460% protein concentration

Ingredient Development for Aquaculture Feeds

2) Mechanical Air-classification of barley and oats

Adaptive Bio-Resources, LLC



12%-30% protein

Too low for a primary protein
High protein carbohydrate source
Multiple product streams

Ingredient Development for Aquaculture Feeds

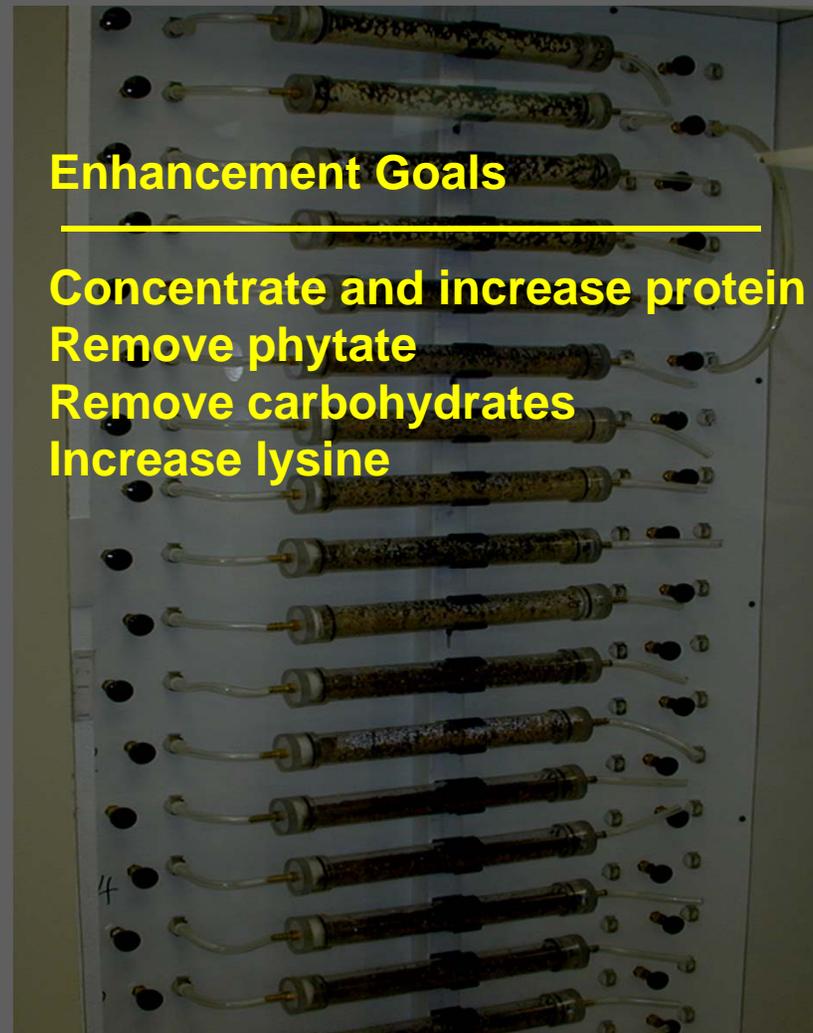
3) Biological Enhancement

Montana Microbial Products



Enhancement Goals

- Concentrate and increase protein
- Remove phytate
- Remove carbohydrates
- Increase lysine



Ingredient Development for Aquaculture Feeds



4) Genetic improvement



Improved Genetic Lines of Soybeans;



Soybeans;

~~Lipoxygenase~~

~~Lectins, mg/kg~~

~~Oligosaccharides; Stachyose, Raffinose~~

~~Trypsin Inhibitor Activity, mg/g~~

~~Saponin, multiple types~~

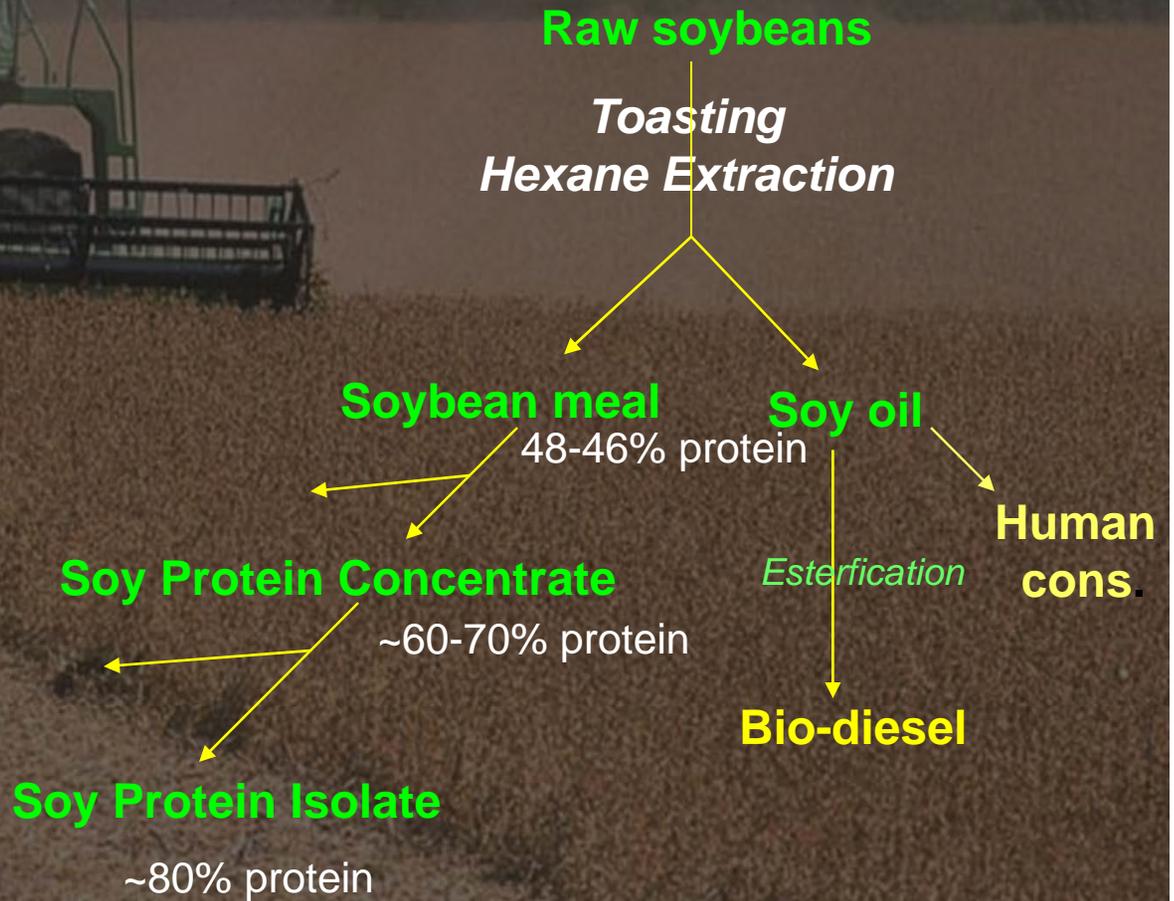
~~Phytate~~

~~P34 allergen~~

All non-GMO

Advances in Sustainable Feeds

Aquaculture Innovation Workshop





Soybeans



Improved Genetic Lines; Full Fat Beans Apparent Digestibility Coefficients

	% Protein	Protein ADC, %	Lysine ADC, %	Dry matter ADC %
Fish, Menhaden Special Select	68			
Commodity soybeans	41			
Low Trypsin cold	44			
Low Trypsin, heated				
Ultra-low Trypsin, cold	43			
Ultra-low Trypsin, heated				
UL Oligo, Very high pro. Cold	49			
UL Oligo, Very high pro. heat				



Soybeans



Improved Genetic Lines; Full Fat Beans Apparent Digestibility Coefficients

	% Protein	Protein ADC, %	Lysine ADC, %	Dry matter ADC %
Fish, Menhaden Special Select	68	89.8	95.6	77.6
Commodity soybeans	41	90.9	94.3	65.1
Low Trypsin cold	44	87.1	92.3	72.0
Low Trypsin, heated		96.3	97.3	76.1
Ultra-low Trypsin, cold	43	93.6	93.0	73.0
Ultra-low Trypsin, heated		100	100	82.8
UL Oligo, Very high pro. Cold	49	100	100	86.5
UL Oligo, Very high pro. heat		99.3	99.8	81.2

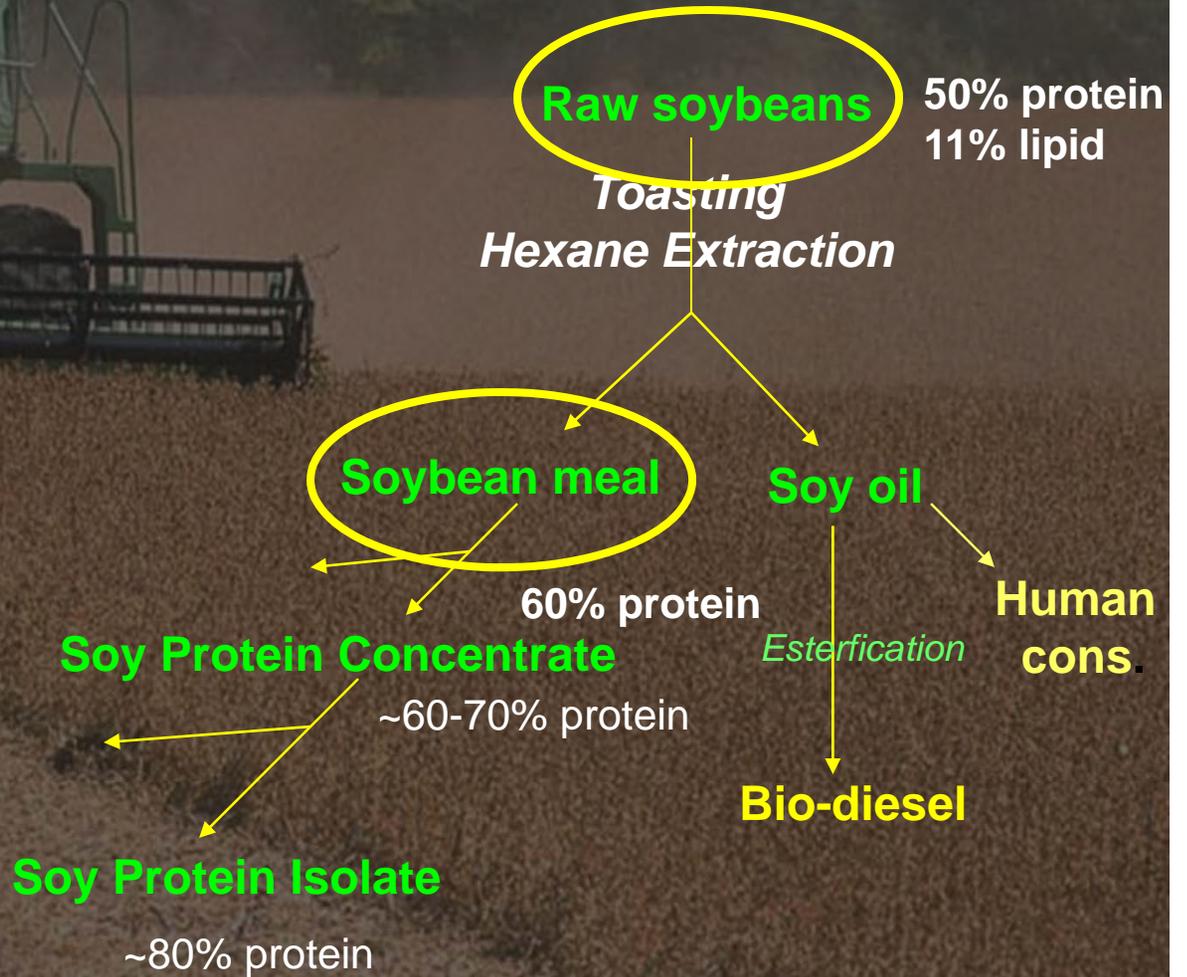
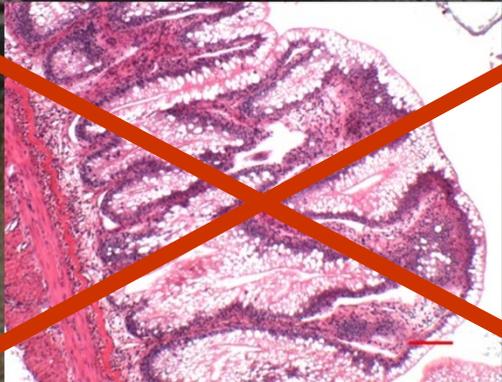
19.5% (difference between Commodity and Low Trypsin cold)

 9% (difference between Low Trypsin cold and Ultra-low Trypsin cold)

 27% (difference between Commodity and UL Oligo Very high pro. Cold)

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Soybeans



Improved Genetic Lines;

Trials in 2011

Trout, laboratory, ARS, growth, functionality & processing

Trout, raceway studies, ARS & Clear Springs Foods

Atlantic Salmon, laboratory, ARS & EWOS Innovation

Atlantic Salmon, production testing, EWOS Innovation

Cobia, laboratory, ARS & Virginia Cobia Farms

Yellowtail, laboratory, ARS & Kona Blue Water Farms

Improved processing, ARS & Adaptive Bio-Resources



3) **Supplementation and species application**

Plant-Based and Fish-Meal Free Trout Feeds

Essential nutrients in fish meal

Amino acids; taurine, lys, met, thr. etc.

Balance to target protein profile

Vitamins; Inositol

Minerals; magnesium, sodium, potassium

Lipids; ?



Supplement to practical fish meal based and plant based diets requirement versus supplementation trials

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

Hubb's Sea World Research Institute
San Diego, CA



Imperial Aquafeeds, LLC
Imperial Valley, CA

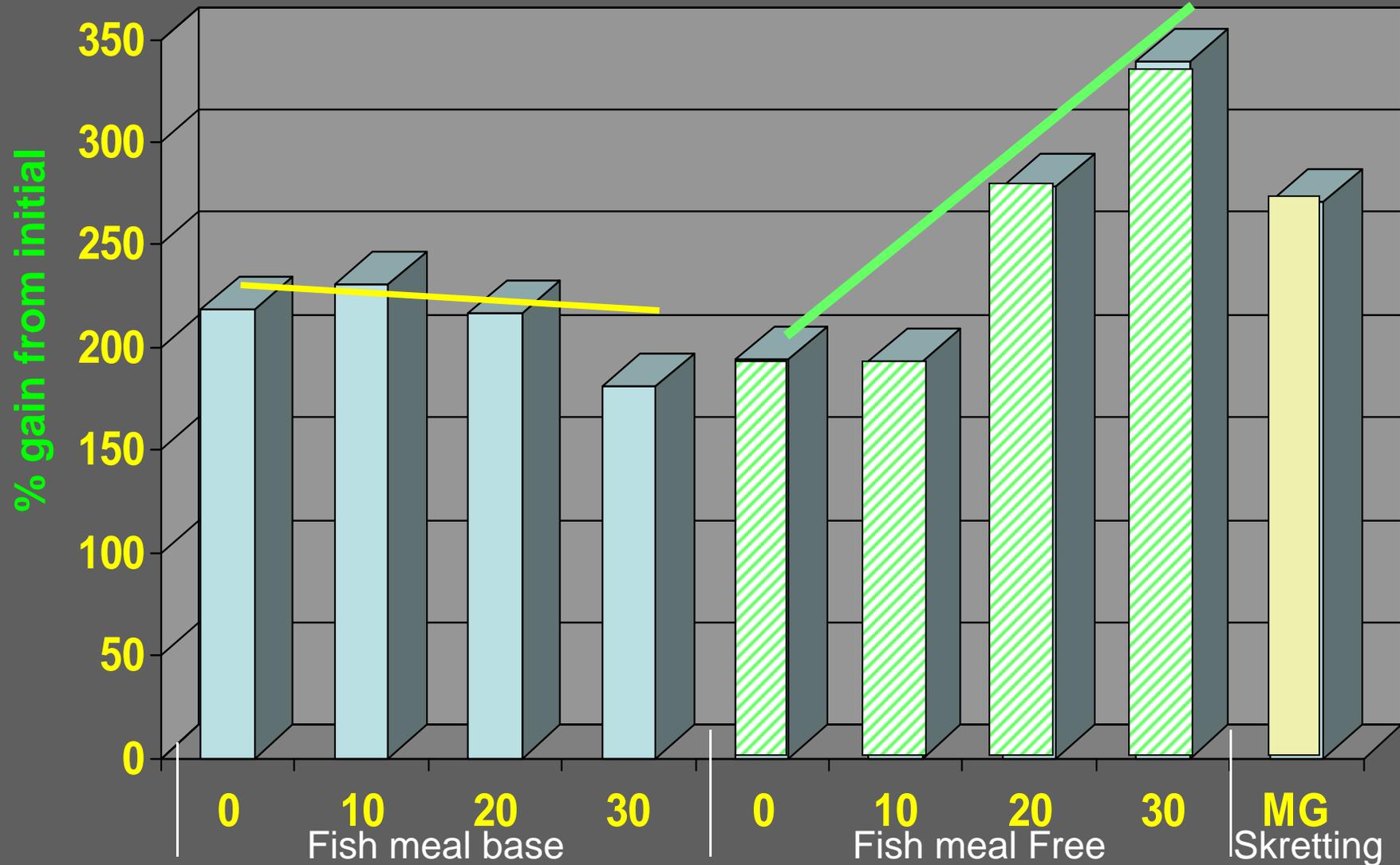


Effect of base formula and added spirulina meal on growth of white sea bass; 8 weeks

Hubb's Sea World Research Institute
San Diego, CA



Imperial Aquafeeds, LLC
Imperial Valley, CA

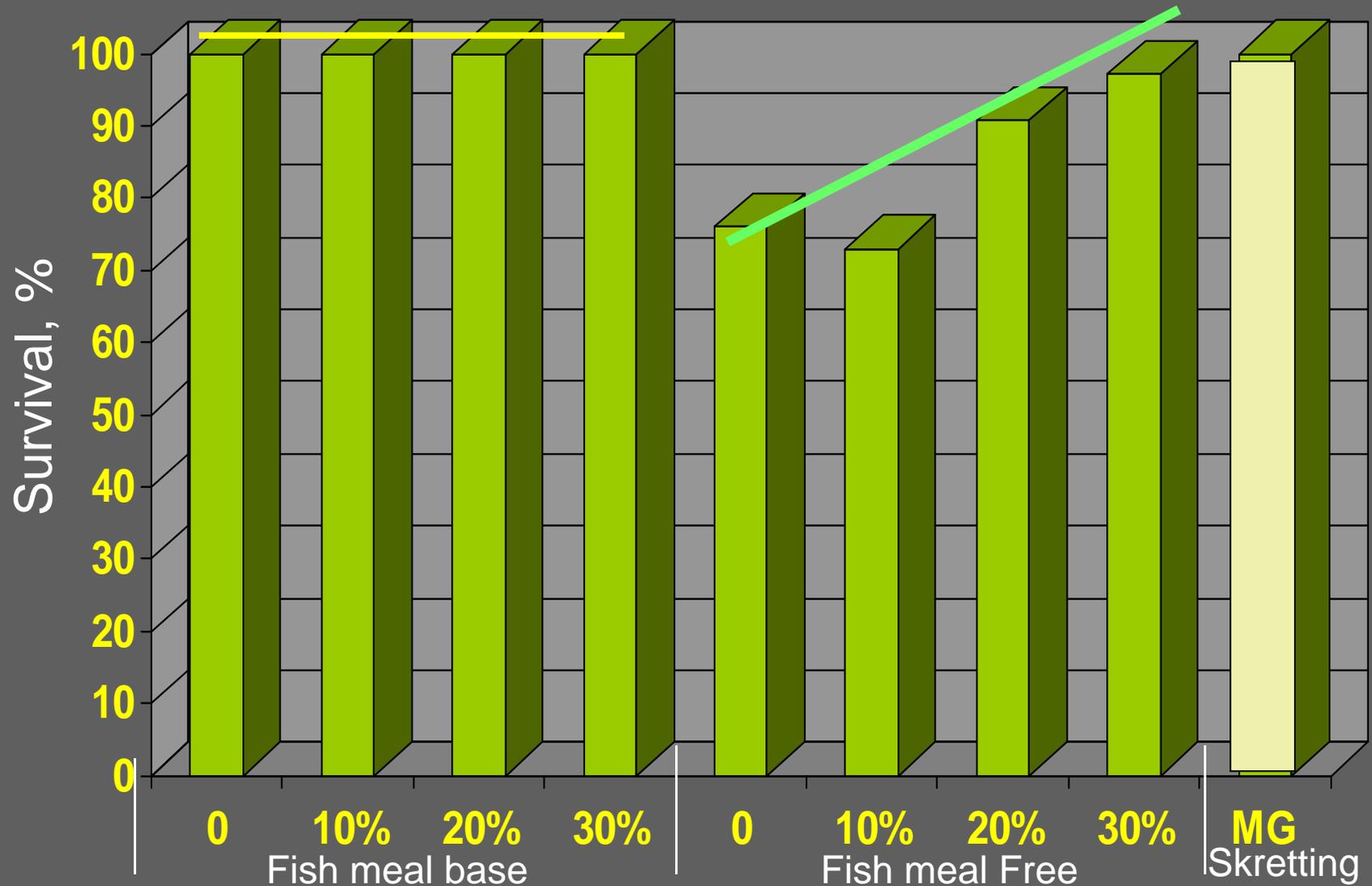


Effect of base formula and added spirulina meal on survival of white sea bass; 8 weeks

Hubb's Sea World Research Institute
San Diego, CA



Imperial Aquafeeds, LLC
Imperial Valley, CA

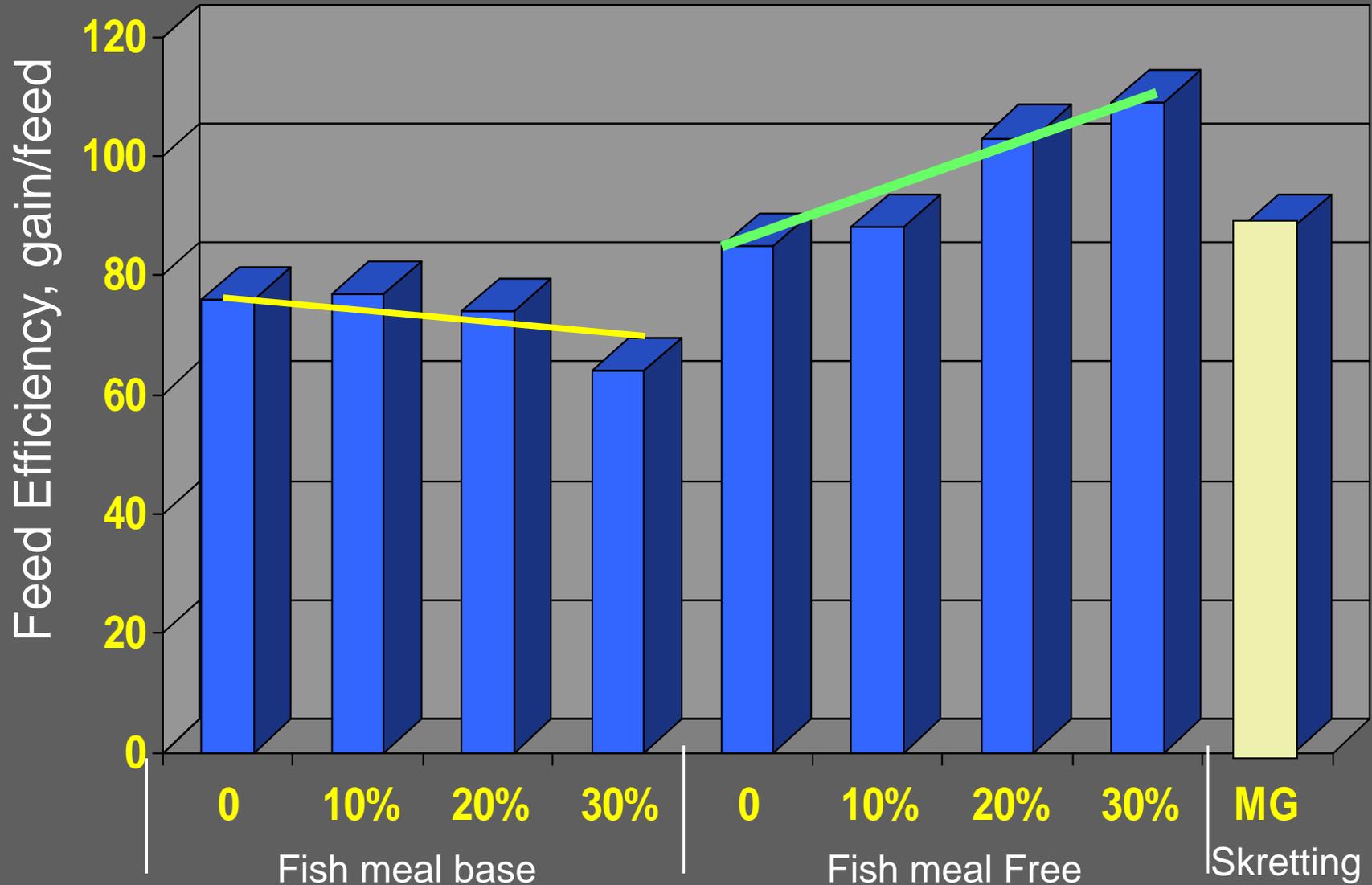


Effect of base formula and added spirulina meal on FCR of white sea bass; 8 weeks

Hubb's Sea World Research Institute
San Diego, CA



Imperial Aquafeeds, LLC
Imperial Valley, CA



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Feed Formulations; Interactions with Re-circulating Aquaculture Systems

Guar gum
Animal products

Total solids and type of solids

Total ammonia nitrogen

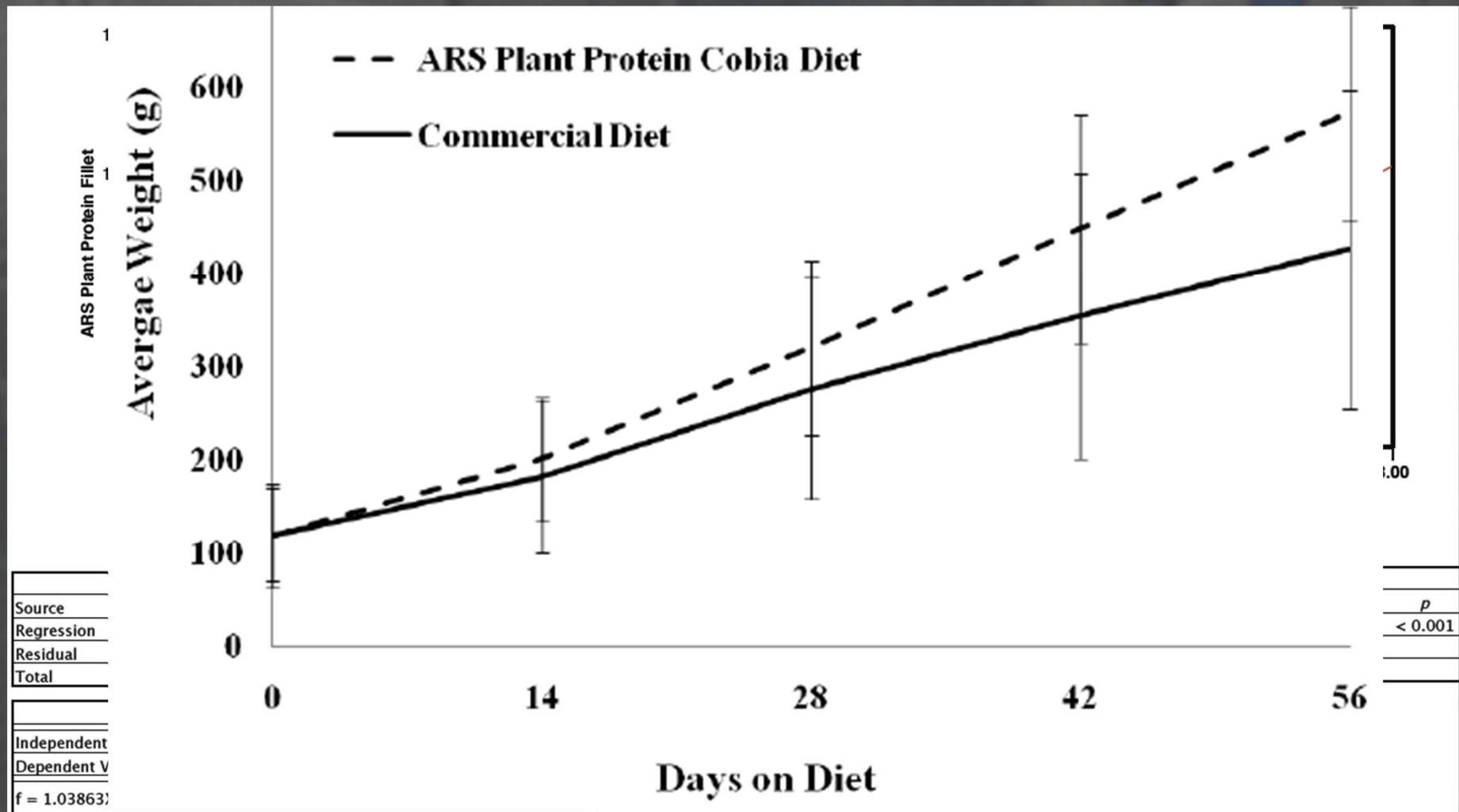
Trace mineral levels



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Total Ammonia Nitrogen; Cobia, Center for Marine Biology, Maryland
Balance available amino acids to a target protein profile



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Feed Formulations; interactions with RAS

Total solids and type of solids

Total ammonia nitrogen

Trace and macro mineral levels

Effluents, bio-floc



Cu source by level by base formula
2 x 4 x 2

Aquaculture Innovation Workshop **Advances in Alternative Feeds**

Summary and Conclusions

- Feeds can be designed for specific rearing conditions
- Increased ingredient selection and increased knowledge of ingredient performance will result in more responsive and cost-effective feeds in the future.
 - Fish meal can be a good ingredient but is not required.

