Evaluation of Algae Co-Products as a Potential Alternative Ingredient for Cattle, Fish and Shrimp Feeds

Biofuels Co-Products Workshop
Waimanalo, Hawaii
December 1-2, 2011

Addison L. Lawrence[1], Tryon A. Wickersham[2], Delbert M. Gatlin III[3], Donovan Patterson[3], Susmita Patnaik[1], Merritt Drewery[2]

[1]Texas AgriLife Research Mariculture Laboratory and Departments of [2]Animal Science and [3]Wildlife and Fisheries Sciences, Texas A&M University, Texas A&M System

TEXAS A&M UNIVERSITY
College of Agriculture and Life Sciences
Department of Animal Science

AgriLIFE RESEARCH
Texas A&M System

WILDLIFE & FISHERIES SCIENCES
TEXAS A&M UNIVERSITY

From Texas A&M University

HOWDY!!!!!!!!!

TEXAS A&M UNIVERSITY

College of Agriculture and Life Sciences

Department of Animal Science

AgriLIFE RESEARCH

Texas A&M System

WILDLIFE & FISHERIES SCIENCES

TEXAS A&M UNIVERSITY


Texas AgriLife Research
Mariculture Laboratory
at Port Aransas
Texas A&M System
AgriLIFE RESEARCH
1300 Port Street

WILDLIFE & FISHERIES SCIENCES
TEXAS A&M UNIVERSITY

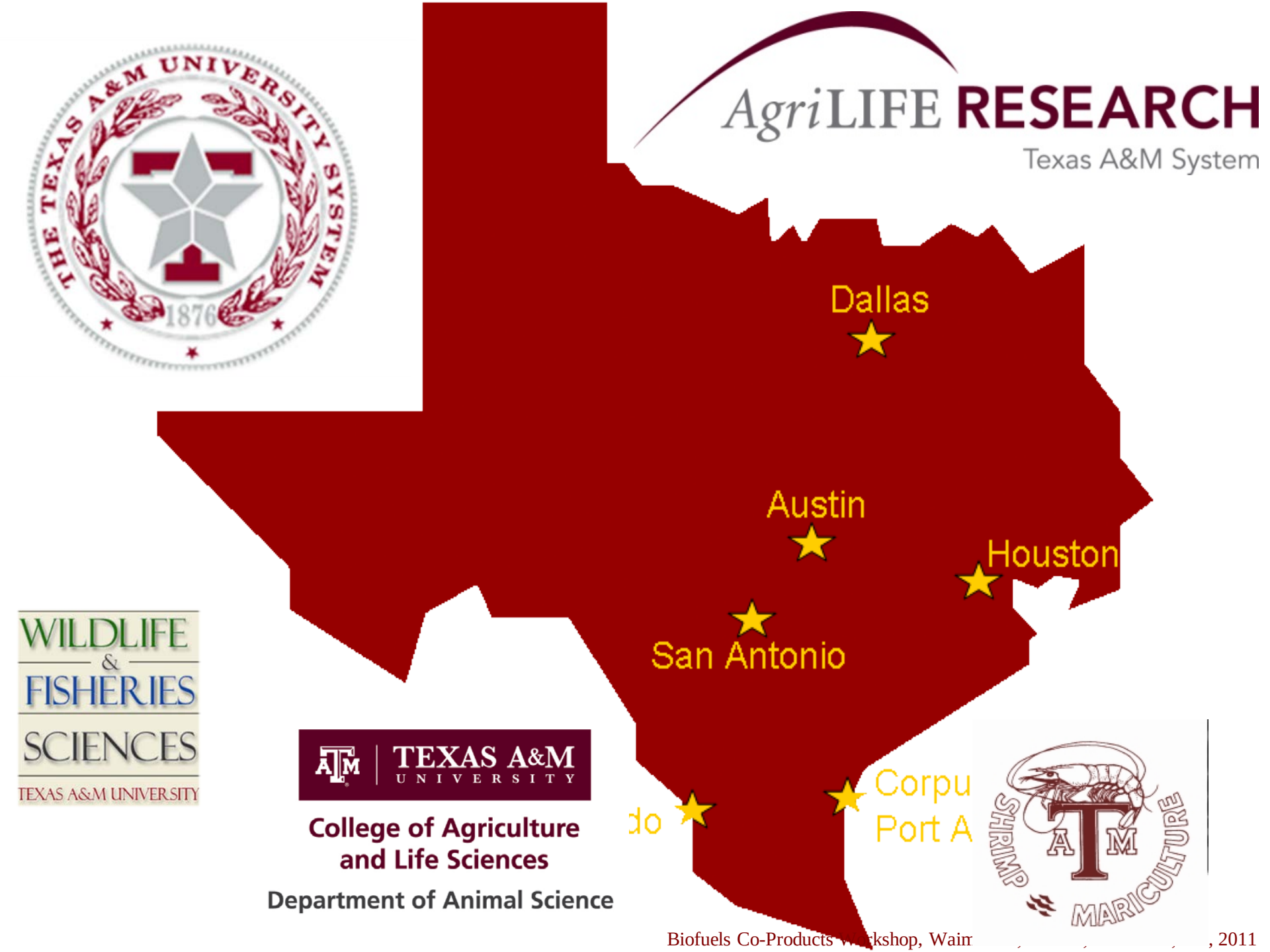
AgriLIFE RESEARCH
Texas A&M System

WILDLIFE & FISHERIES SCIENCES
TEXAS A&M UNIVERSITY

TEXAS A&M UNIVERSITY

College of Agriculture and Life Sciences

Department of Animal Science


THE TEXAS A&M UNIVERSITY SYSTEM
1876
AgriLIFE RESEARCH
Texas A&M System
Dallas
Austin
Houston
San Antonio
Corpu
Port A
WILDLIFE
&
FISHERIES
SCIENCES
TEXAS A&M UNIVERSITY
TEXAS A&M
UNIVERSITY
College of Agriculture
and Life Sciences
Department of Animal Science
SHRIMP
MARICULTURE

Alternative Feed Ingredient Program

- Grain ingredients (e.g. dehulled defatted soybean meal, canola, lupin, pea meals, etc.)
- Grain concentrates (e.g. soybean concentrate, wheat gluten, corn gluten, canola, etc.)
- Animal meals (e.g. poultry by-products, blood meal, meat and bone meal)
- Dried distiller grain with solubles (DDGS) by-product from brewery and biofuel industries
- Biofloc from aquaculture waste made by SBR's and MBR's
- Seafood processing by-products co-extruded with grain ingredients (e.g. soybean meal)
- Algae co-products (defatted algae)

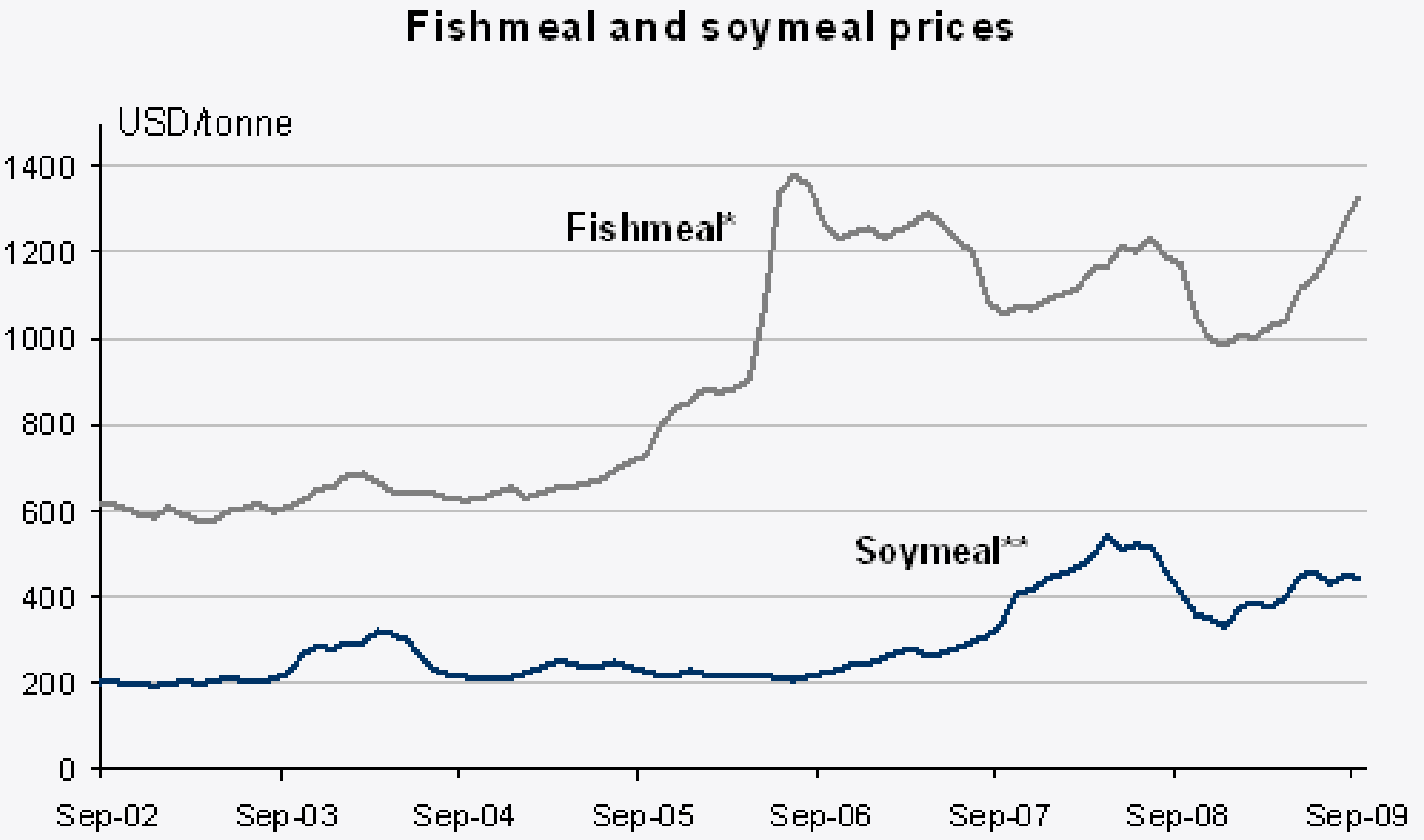
AgriLIFE RESEARCH
Texas A&M System

Questions Asked By A&M??????

- What ingredients should be replaced? – criteria: volume and cost – chose soybean, fish, cottonseed, and DDGS meals
- What species should be evaluated? – criteria: volume and cost – chose fish, shrimp and cattle

AgriLIFE RESEARCH
Texas A&M System

Fish and Soybean Meals Prices



Algae Co-Product (defatted algae) Cattle Feed

- Economic value
- High nutritional value
- DDGS replacement
- Unknown growth factors

AgriLIFE RESEARCH
Texas A&M System

Algae Co-Product (defatted algae) Fish and Shrimp Feeds

- Economic value
- High nutritional value
- Fish meal replacement
- Fish oil replacement
- Soybean meal replacement
- Unknown growth factors

AgriLIFE RESEARCH
Texas A&M System

Fish Meal for Shrimp and Fish

- **ADVANTAGES**

  Source of dietary protein, minerals, highly unsaturated fatty acids, chemoattractants, and unknown growth factors.

- **DISADVANTAGES**

  Expensive with supply not sustainable.

AgriLIFE RESEARCH
Texas A&M System

DDGS Meal for Cattle

- **ADVANTAGES**

  Source of dietary protein, minerals, vitamins, and unknown growth factors.

- **DISADVANTAGES**

  High sulfur levels, variable, and difficult to handle.

AgriLIFE RESEARCH
Texas A&M System

Objective

TO EVALUATE DEFATTED ALGAE AS A MEAL FOR CATTLE AND MARINE FISH AND SHRIMP DIETS

AgriLIFE RESEARCH
Texas A&M System

Algae Information

- Species of Algae
- Production Method
- Oil Extraction Method
- Chain of Custody

AgriLIFE RESEARCH
Texas A&M System

Proximate composition of Whole Algae and Defatted Algae (diatom)

Proximate analysis of algae as diet ingredient		
Nutrient (as is bases)	Whole Algae	Defatted Algae
Moisture (%)	7.81	3.62
Dry Matter (%)	92.2	96.4
Crude Protein (%)*	16.2	11.9
Crude Fat (%)*	10.7	0.59
Acid Detergent Fiber (%)*	<0.5	<0.5
Ash (%)*	36.9	49.1

* Values as % on "as is' basis"

Base (control) Diet (BD) and Standard Semi-Purified Research Diet (SSPRD) Ingredient Levels (as-fed basis) for Shrimp

Ingredient (%)	SSPRD	BD	Ingredient (%)	SSPRD	BD
Alginate	2.00	2.00	Oil, Soybean	0.60	2.70
Ca Carbonate	2.50	2.60	Phospholipid,97%	4.00	2.40
Cellulose	3.20	2.20	$CaHPO_4$	4.20	2.30
Cholesterol	0.20	0.20	$NaHexaMetaPO_4$	1.00	1.00
CuSO4*H2O	0.00	0.03	Poultry By-Product	0.00	5.00
Diatomaceous Earth	3.80	1.40	PM Min/Vit LMCI	0.25	0.25
Fish, Menhaden	8.00	15.0	PM Min/Vit LMCI	0.21	0.21
KCl	1.90	2.00	Soybean-90%	5.70	19.70
L-Methionine	0.00	0.10	Squid, Muscle	30.0	6.00
MgO	1.60	1.40	Vit C, Staple 35%	0.04	0.04
NaCl	0.70	0.20	Wheat Starch	29.5	32.9
Oil, Fish Menhaden	0.60	0.40			

Whole Algae, Defatted Algae (Algae Co-Product), Fish Meal (menhaden) and Isolated Soy 90% Protein Meal Levels in Base (control) and Experimental Diets (as-fed basis) for Shrimp

	Base	11-0	11-0	11-0	11-0	11-0	11-0	11-0	11-0
Ingredient (%)	Diet	901a	901b	903a	903b	905a	905b	907a	907b
Algae, Whole		6.67	13.3	6.51	13.2	0.00	0.00	0.00	0.00
Algae, Defatted		0.00	0.00	0.00	0.00	6.67	13.3	6.67	13.3
Fish, Menhaden	15.0	15.0	15.0	13.3	11.5	15.0	15.0	13.7	12.3
Soybean-90%	19.7	18.5	17.3	19.7	19.7	18.8	17.8	19.7	19.7

AgriLIFE RESEARCH
Texas A&M System

Base and Experimental Diet Ingredients for Shrimp which were constant (as-fed bases)

Ingredient	Level (%)	Ingredient	Level (%)
Alginate	2.00	PM Min/Vit LMCI	0.25
Cholesterol	0.20	PM Min/Vit LMCI	0.21
CuSO4*H2O	0.03	Squid, Muscle	6.00
L-methionine	0.10	Lecithin, 97%	2.40
NaHexaMetaPO4	1.00	Vit C, Staple 35%	0.04
Poultry By-Prdct	5.00		

AgriLIFE RESEARCH
Texas A&M System

Base and Experimental Diet Ingredients for Shrimp which were varied to maintain some dietary nutrients constant (as-fed basis)

	Base	11-0	11-0	11-0	11-0	11-0	11-0	11-0	11-0
Ingredient (%)	Diet	901a	901b	903a	903b	905a	905b	907a	907b
Ca Carbonate	2.60	1.87	1.13	2.08	1.55	1.73	0.87	1.73	0.87
Cellulose	2.20	2.17	2.13	2.17	2.13	2.17	2.13	2.17	2.13
Diatomaceous Earth	1.40	0.93	0.47	0.94	0.48	0.93	0.47	0.93	0.47
KCl	2.00	1.63	1.27	1.64	1.28	1.70	1.40	1.73	1.47
MgO	1.40	1.37	1.33	1.37	1.33	1.33	1.27	1.33	1.27
NaCl	0.20	0.13	0.07	0.13	0.07	0.13	0.07	0.13	0.07
Oil, Fish Menhaden	0.40	0.40	0.40	0.56	0.73	0.40	0.40	0.53	0.67
Oil, Soybean	2.70	1.80	0.90	1.82	0.92	2.40	2.10	2.37	2.03
CaHPO4	2.30	2.17	2.03	2.17	2.04	1.97	1.63	2.30	2.30
Wheat Starch	32.9	30.1	27.4	30.4	27.8	29.6	26.3	29.5	26.1

AgriLIFE RESEARCH
Texas A&M System

Nutrient Profiles of Shrimp Diets (analyzed values)

% Nutrients (as fed bases)	StRef Diet	Base Diet	11-0901a	11-0901b	11-0903a	11-0903b	11-0905a	11-0905b	11-0907a	11-0907b
Moisture	8.49	8.45	8.65	9.68	8.86	9.03	8.09	8.65	8.35	9.67
Crude Protein	38.7	37.2	36.1	35.6	35.6	36.8	36.9	36.3	36.2	35.2
Crude Fat	6.19	7.64	6.78	8.52	8.15	7.18	7.27	7.60	6.71	5.96
Fiber	2.26	3.25	2.46	3.84	4.24	4.60	4.04	4.13	4.96	4.97
Ash	17.6	16.2	17.5	18.4	17.1	17.4	18.1	18.7	17.9	19.9
Sulfur		0.39	0.42	0.44	0.40	0.42	0.41	0.44	0.41	0.45
Phosphorus		2.06	2.06	1.99	1.84	1.82	1.85	1.76	1.87	1.88
Potassium		1.34	1.25	1.09	1.14	1.03	1.16	1.09	1.19	1.13
Magnesium		1.52	1.26	1.69	1.51	1.36	1.60	1.32	1.39	1.54
Calcium		3.36	3.07	2.63	2.73	2.44	3.41	3.58	3.44	3.74
Sodium		0.95	1.04	1.12	1.00	1.08	1.06	1.20	1.05	1.24
Iron (ppm)		553	586	783	962	616	590	414	481	468
Manganese (ppm)		54.0	54.0	68.0	58.0	59.0	56.0	50.0	51.0	56.0
Copper (ppm)		120	116	126	111	128	122	118	120	132
Zinc (ppm)		155	157	156.	148	151	144	144	146	148

Methods for Shrimp Experiment

- 6 shrimp tank (bottom area 0.1m^2) or 60/m^2 of similar size (0.588 g) were stocked in a tank.
- 8 replicates each dietary treatment.

Methods for Shrimp Experiment

- Temperature: 30 ± 2ºC Salinity: 26- 36 ppt
- Feed Rate: Above satiation, 15 times daily
- Photoperiod: 12h day and 12 h night
- Dissolved oxygen: 5.20 ± 0.2 mg/L
- Water exchange rate (new water): 144%/day
- Daily removal of feces and dead shrimp
- Weekly monitoring of ammonia, nitrite, nitrate, pH.
- Daily monitoring of dissolved oxygen, temperature and salinity

AgriLIFE RESEARCH
Texas A&M System

Methods for Shrimp Experiment

- Feed prepared by cold extrusion.
- Temperature controlled, recirculating system
- Water exchange: regulated by flow restrictor inserted in the inflow fitting.
- All diets were fed in excess of consumption, fifteen times daily using automatic feeders
- Uneaten feed and feces removed daily from tanks
- Critical water quality indicators were maintained to be not limiting shrimp growth
- Trial length: <u>36 days</u>

AgriLIFE RESEARCH
Texas A&M System

Statistical Analyses for Shrimp Exp.

- Mean final weight, survival, growth, and harvest biomass data were analyzed among treatments ($\alpha = 0.05$) using SPSS 15.0 statistical software (SPSS Inc. Chicago, Il)
- One-way ANOVA used to determine significant differences among treatments

AgriLIFE RESEARCH
Texas A&M System

Survival(%), final weight(g), and growth(g/wk) values for *L. vannamei* fed diets using whole and defatted algae as feed ingredients.

AW: Algae whole; AD: Algae defatted; FM: Fish meal; SB: Soybean meal

AW	AD	FM	SB	Survival	Final Wt.	Growth
0.00	0.00	15.00	5.7	100.±0.0	12.7±0.6	2.34±0.10
0.00	0.00	15.00	19.7	96.7±7.4	10.5±0.4	1.92±0.11
6.67	0.00	15.00	18.5	94.4±8.6	10.3±0.6	1.87±0.12
13.33	0.00	15.00	17.3	91.7±9.1	10.1±0.5	1.85±0.11
6.51	0.00	13.00	19.7	97.2±6.8	10.0±0.4	1.81±0.08
13.17	0.00	11.57	19.7	94.4±8.6	10.0±0.5	1.82±0.09
0.00	6.67	15.00	18.8	97.2±6.8	9.3±0.6	1.69±0.12
0.00	13.33	15.00	17.8	83.3±6.8	9.9±0.7	1.80±0.14
0.00	6.67	13.67	19.7	97.2±6.8	9.8±0.9	1.78±0.18
0.00	13.33	12.30	19.7	83.3±6.8	9.7±0.3	1.77±0.05

For the conditions of this experiment:

CONCLUSIONS

- SRD: Maximum growth (2.34 g/wk), 100% survival
- Water quality desirable.
- Shrimp survival ranged from 83.3% to 100% at the end of 36 day trial. No significant difference in survival between any diets
- Shrimp final weight ranged from 8.3 to 10.5 g at termination with no significant difference between the algae diets and the base diet without any algae.
- Shrimp growth ranged from 1.69 to 1.92 g at termination with no significant difference between the algae diets and the base diet without any algae.

AgriLIFE RESEARCH
Texas A&M System

For the conditions of this experiment:

CONCLUSIONS

- Biomass ranged from 163.5 g/m^2 (660.4 g/m3) to 182.9 g/m^2 (739.0 g/m3) with no significant difference between algae diets and base diet without any algae.
- 6.67% whole algae and 13.3% defatted algae can replace fish meal and isolated soy protein on a protein bases with no significant reduction in growth or survival.
- These data indicate that whole or defatted algae can be used as ingredients in shrimp diets as replacements of fish meal, and isolated soybean meal in shrimp diets.

AgriLIFE RESEARCH
Texas A&M System

Reference Diet for Red Drum

(formulated to contain 40% crude protein and 10% lipid)

Ingredient	g/100 g
Menhaden fishmeal	27.8
Soybean Protein Concentrate	27.8
Dextrin	9.0
Menhaden oil	7.0
Vitamin premix	3.0
Mineral premix	3.0
CMC	2.0
Celufil	20.4
Σ	100.0

AgriLIFE RESEARCH
Texas A&M System

Replacement of 5% Dietary Protein with Lipid-Extracted Algae (LEA) and Non-LEA

(formulated to contain 40% crude protein and 10% lipid)

	5% LEA	5% Non-LEA
Ingredient	g/100 g	g/100 g
Menhaden fishmeal	26.4	26.4
Soybean Protein Concentrate	26.4	26.4
Dextrin	9.0	9.0
Menhaden oil	6.5	5.3
Vitamin premix	3.0	3.0
Mineral premix	3.0	3.0
CMC	2.0	2.0
Algae Meal (Defatted or Non- defatted)	15.0	10.3
Celite (diatomaceous earth)	8.0	11.4
Celufil	0.7	3.2
Σ	100.0	100.0

LEA and non-LEA replacement 10% of dietary protein

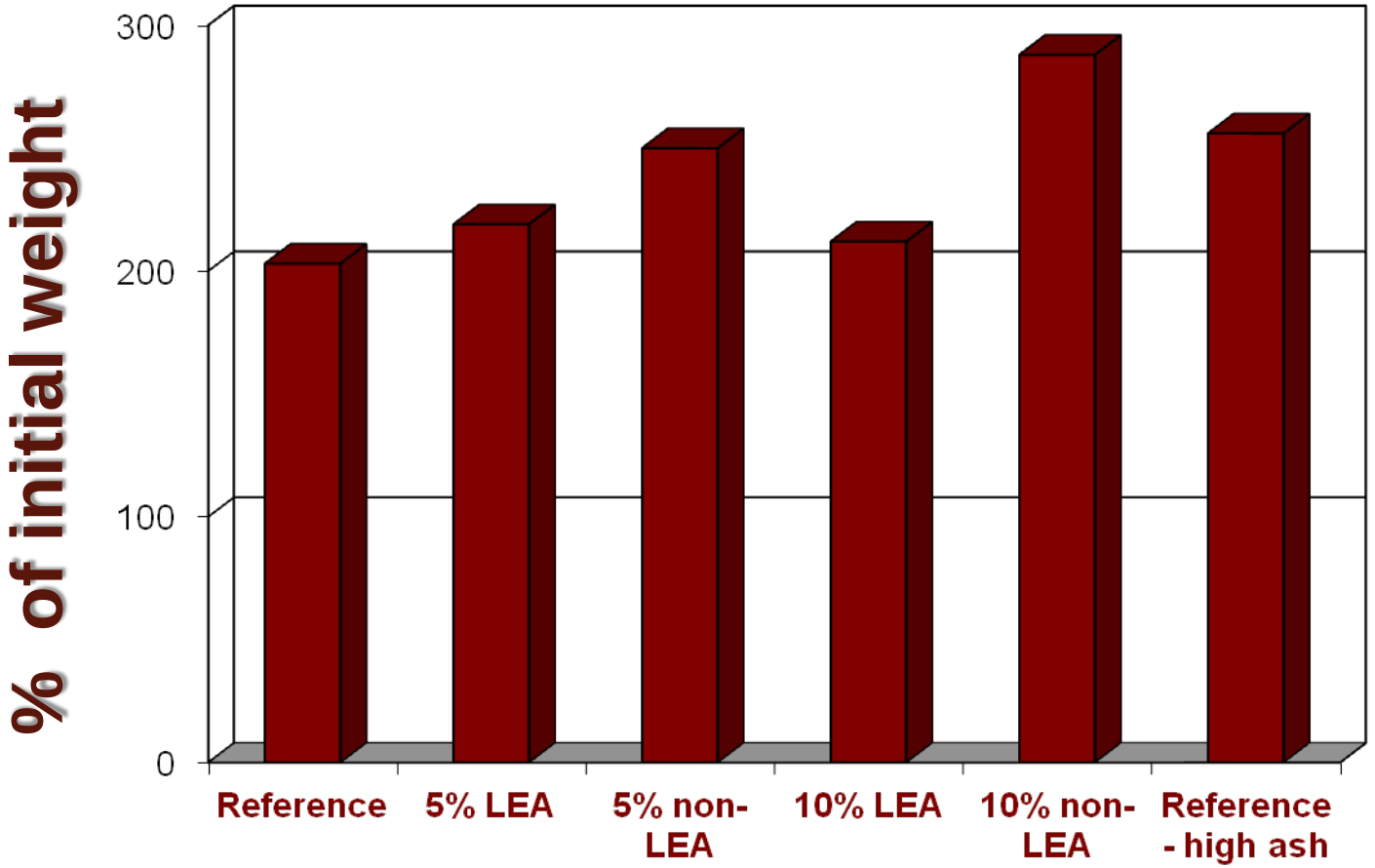
(diets formulated to contain 40% crude protein and 10% lipid)

Ingredient	Reference – high ash	10% LEA	10% Non-LEA
	g/100 g	g/100 g	g/100 g
Menhaden fishmeal	27.80	25.0	25.0
Soybean protein concentrate	27.80	25.0	25.0
Dextrin	9.00	6.1	9.0
Menhaden oil	7.00	5.9	3.4
Vitamin premix	3.00	3.0	3.0
Mineral premix	3.00	3.0	3.0
Carboxymethyl cellulose	2.00	2.0	2.0
Algae Meal (LEA or Non- LEA)		30.0	20.6
Celite (diatomaceous earth)	16.0	0.0	6.8
Celufil	4.40	0.0	2.2
Σ	100.0	100.0	100.0

Feeding Trials at the Aquacultural Research and Teaching Facility

- Experimental culture system
  - 110-L aquaria
  - Temperature 27 ± 1 C
  - Dissolved oxygen near air saturation
  - 12:12 h light:dark cycle
- Red drum (*Sciaenops ocellatus*)
  - 13 g initial weight
  - 7-week feeding trial

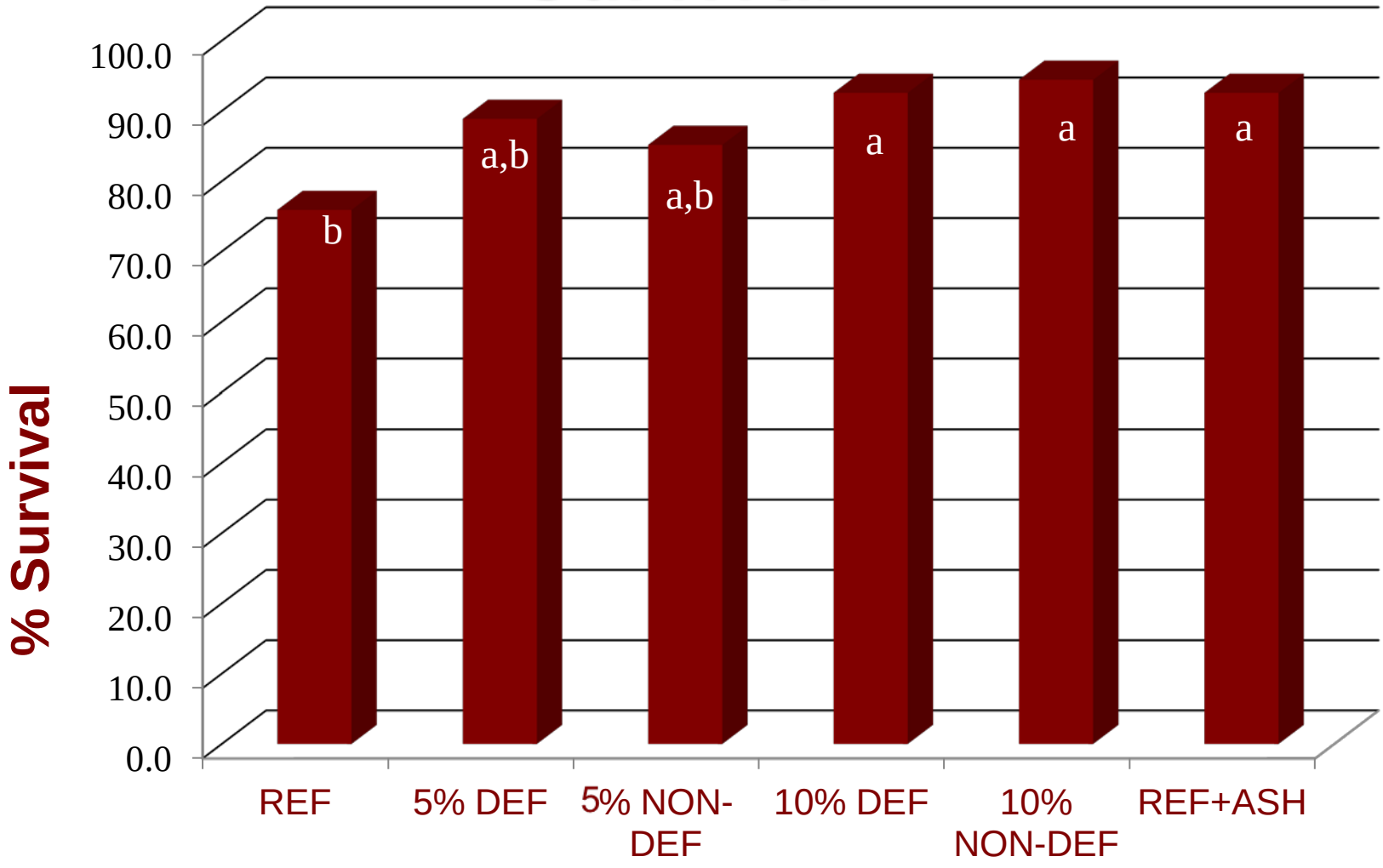
Weight Gain



Diet

P = 0.169

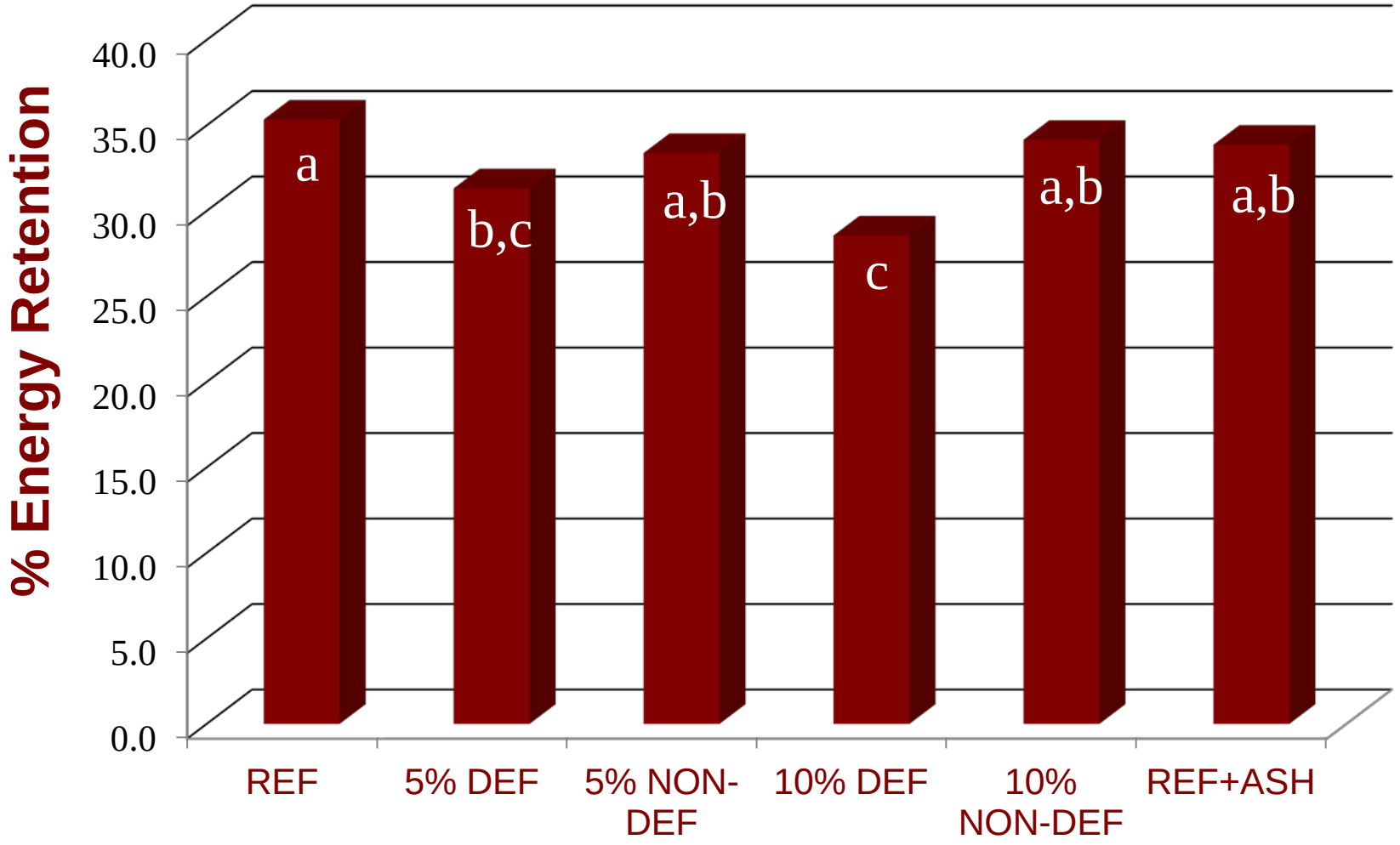
Survival



Supplement (% of diet)

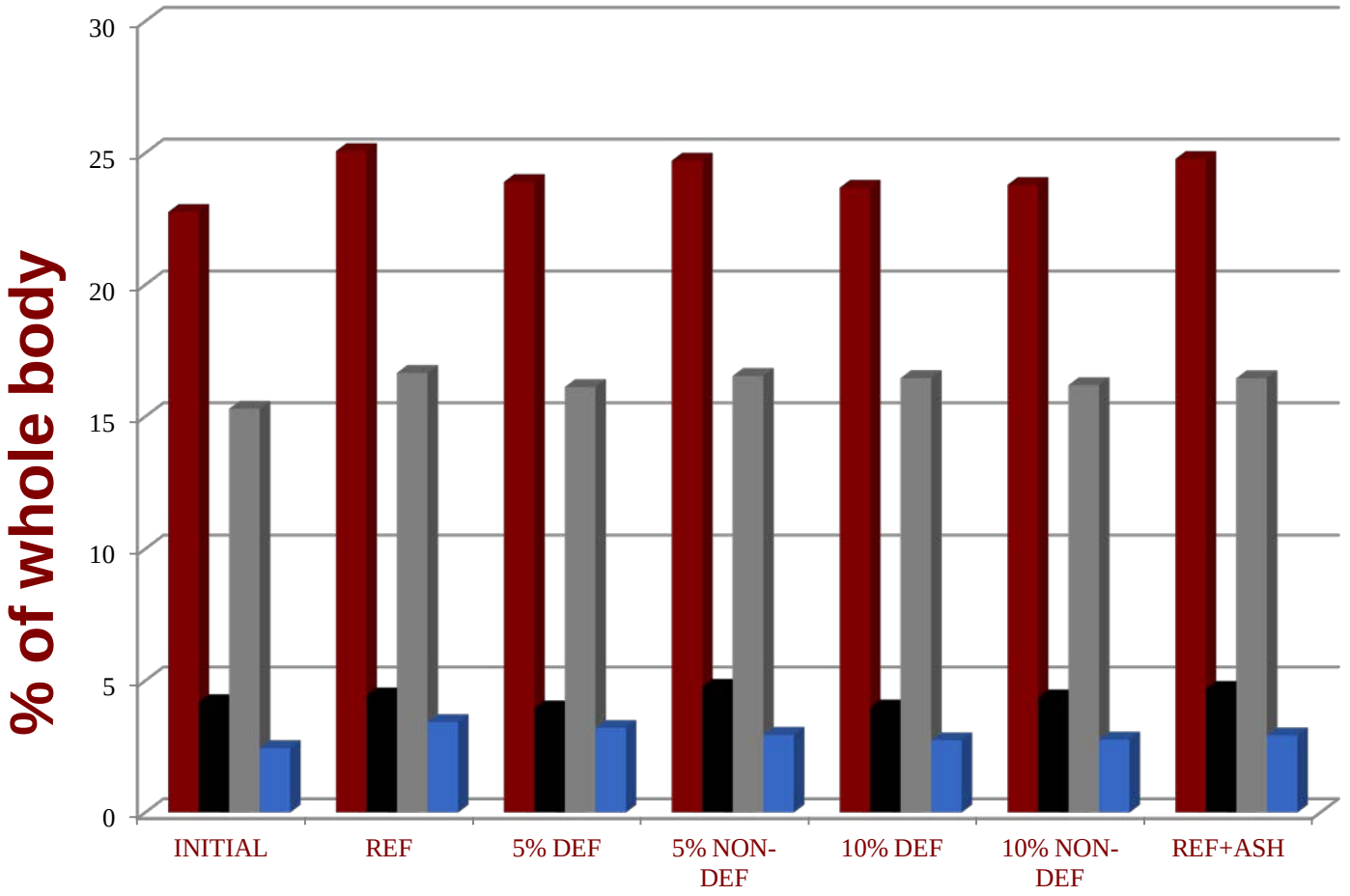
P=.0748

% Energy Retention



P=.0168*

Proximate Composition



P=.3796

P=.4807

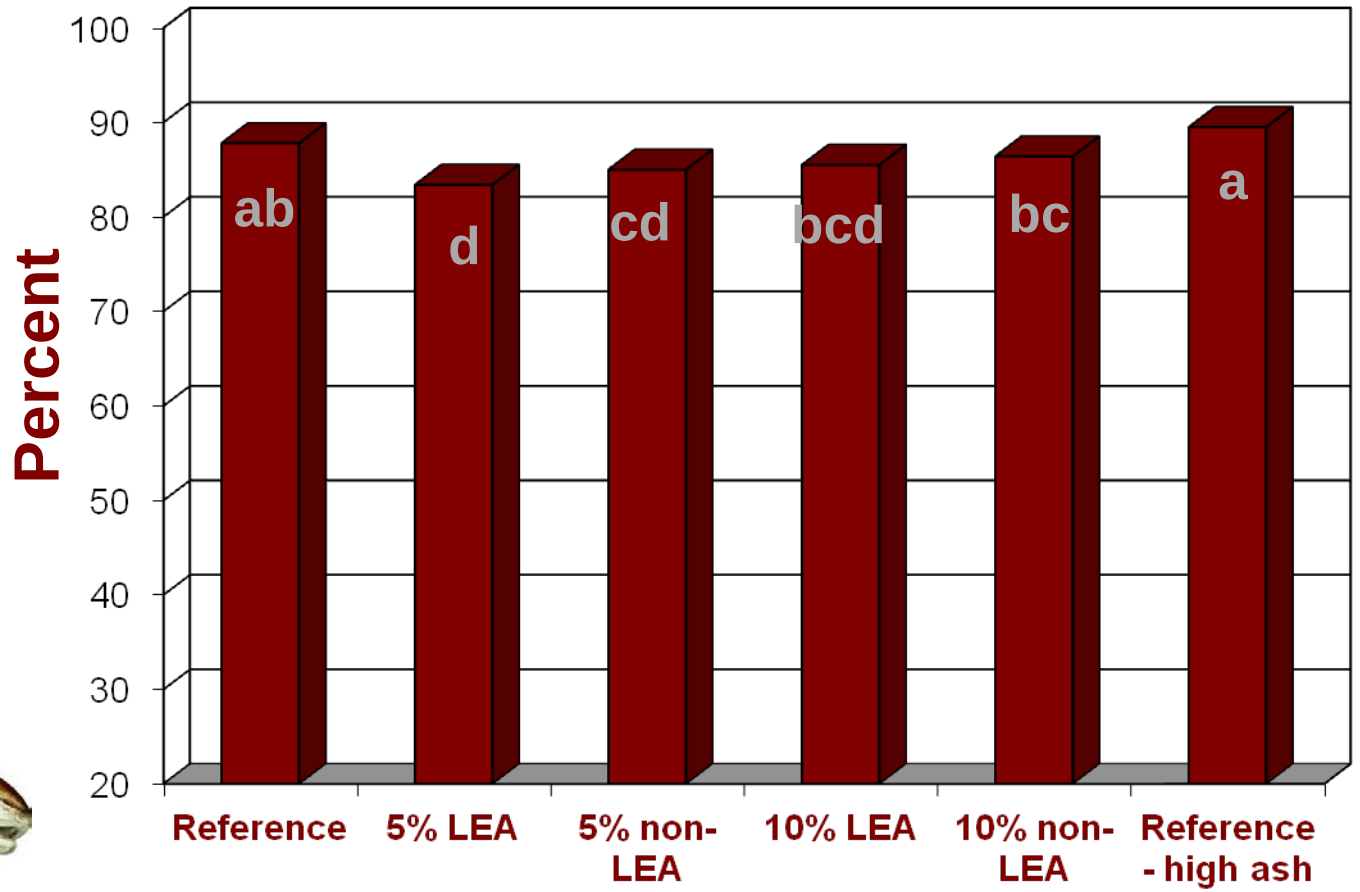
P=.9793

P=.3821

Supplement (% of diet)

AgriLIFE RESEARCH
Texas A&M System

Protein Digestibility Coefficient



Diet

P = 0.0031

AgriLIFE RESEARCH
Texas A&M System

For the conditions of this experiment:

CONCLUSIONS

- Fish fed whole or defatted algae had higher % weight gain but there were no significant differences.
- Survival of fish fed diets containing either 10% whole or defatted algae was significantly greater than fish fed reference diet.
- % energy retention for fish fed diets containing whole or defatted algae was lower than for fish fed reference diet.
- There were no differences is proximate composition for fish fed any of the diets.
- Protein digestibility for fish fed algae was less that those fed reference diet with the 5% level significant.

Lipid Extracted Algae as a Protein Supplement

- Lipid extracted algae in the cow-calf industry
  - Compete with SBM & CSM
    - SBM: 54% protein, <2% lipid; $440/ton
    - CSM: 48.9% protein, <2% lipid; $448/ton
- Keys to value
  - Higher crude protein content
  - Reduced ash content
  - Material form /adding value

AgriLIFE RESEARCH
Texas A&M System

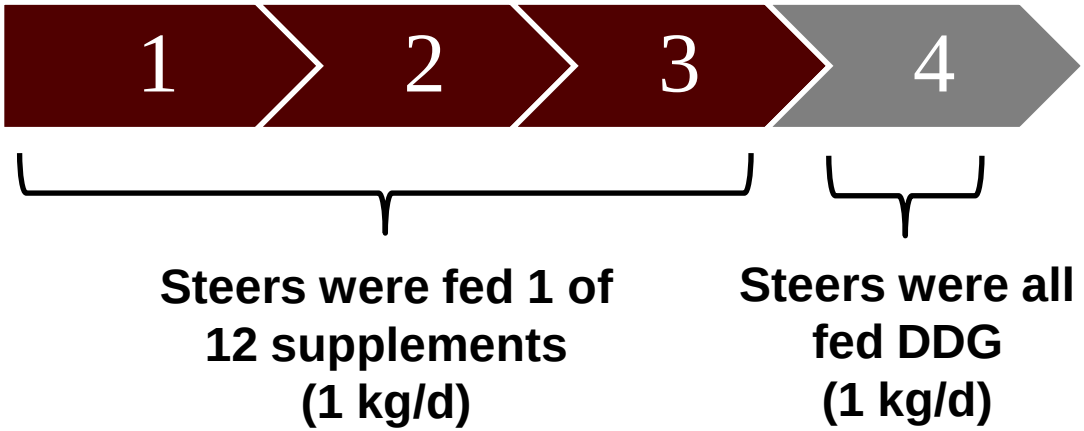
3 Current Projects

- **Exp. 1: Evaluate the palatability of lipid extracted algae at divergent inclusion levels and with differing carriers as a supplement to cattle consuming forage**
- **Exp. 2: Determine the effect of increasing the amount of supplemental lipid extracted algae delivered on forage utilization in steers**
- **Exp. 3: Determine the effect of lipid extracted algae on the utilization of low-quality forage**

AgriLIFE RESEARCH
Texas A&M System

Exp. 1 Palatability

- Angus steers in a 12 × 12 Latin square
- 12 4-d periods



- Hay offered at 2% of BW at 0600 h
- Supplement offered at 1200 h
- Rate of intake was observed; after 1-h, any refusals were collected, weighed & sampled

Experiment 1

Hay – 0600 h

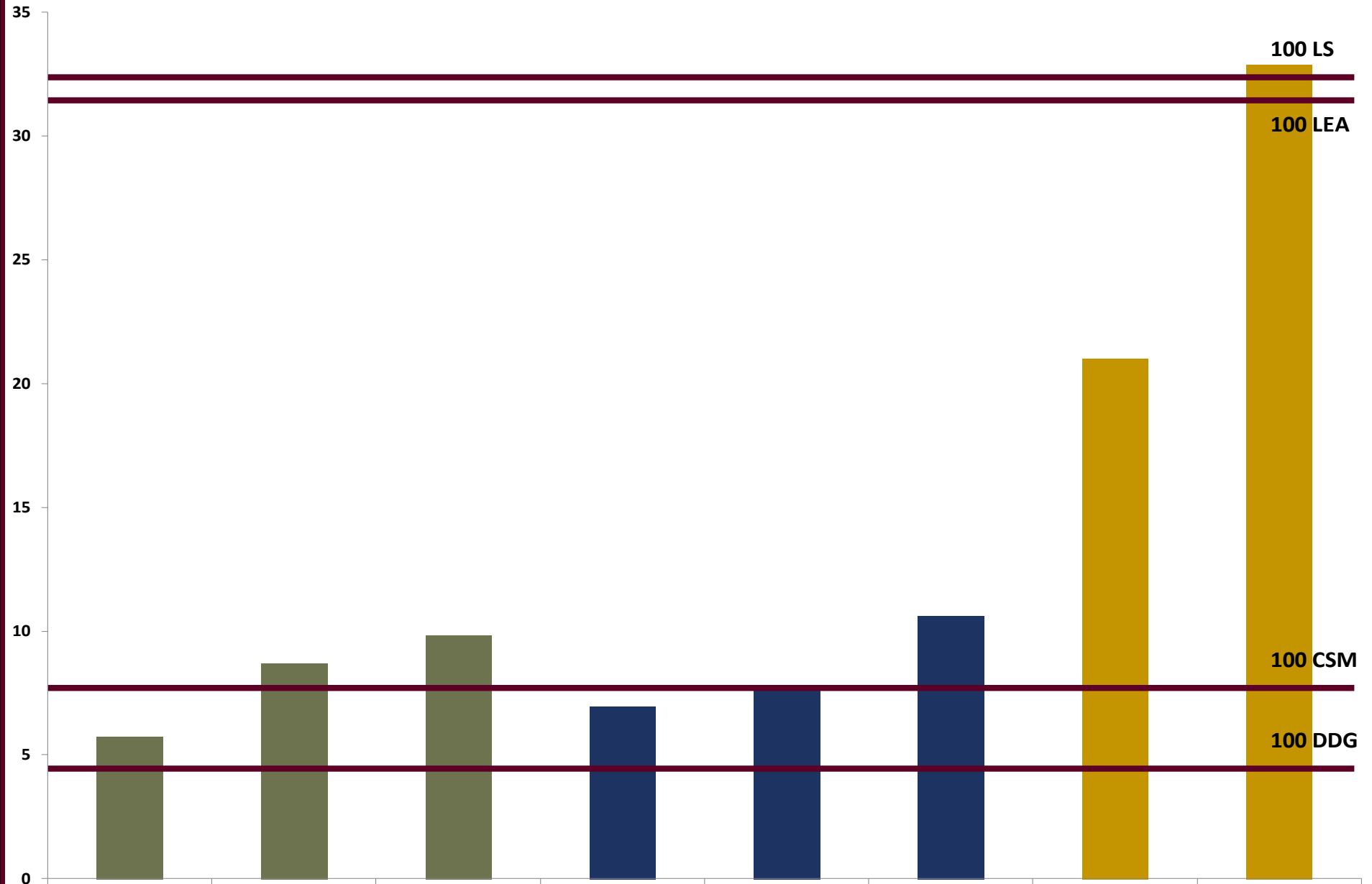
Supplement – 1200 h

AgriLIFE RESEARCH
Texas A&M System

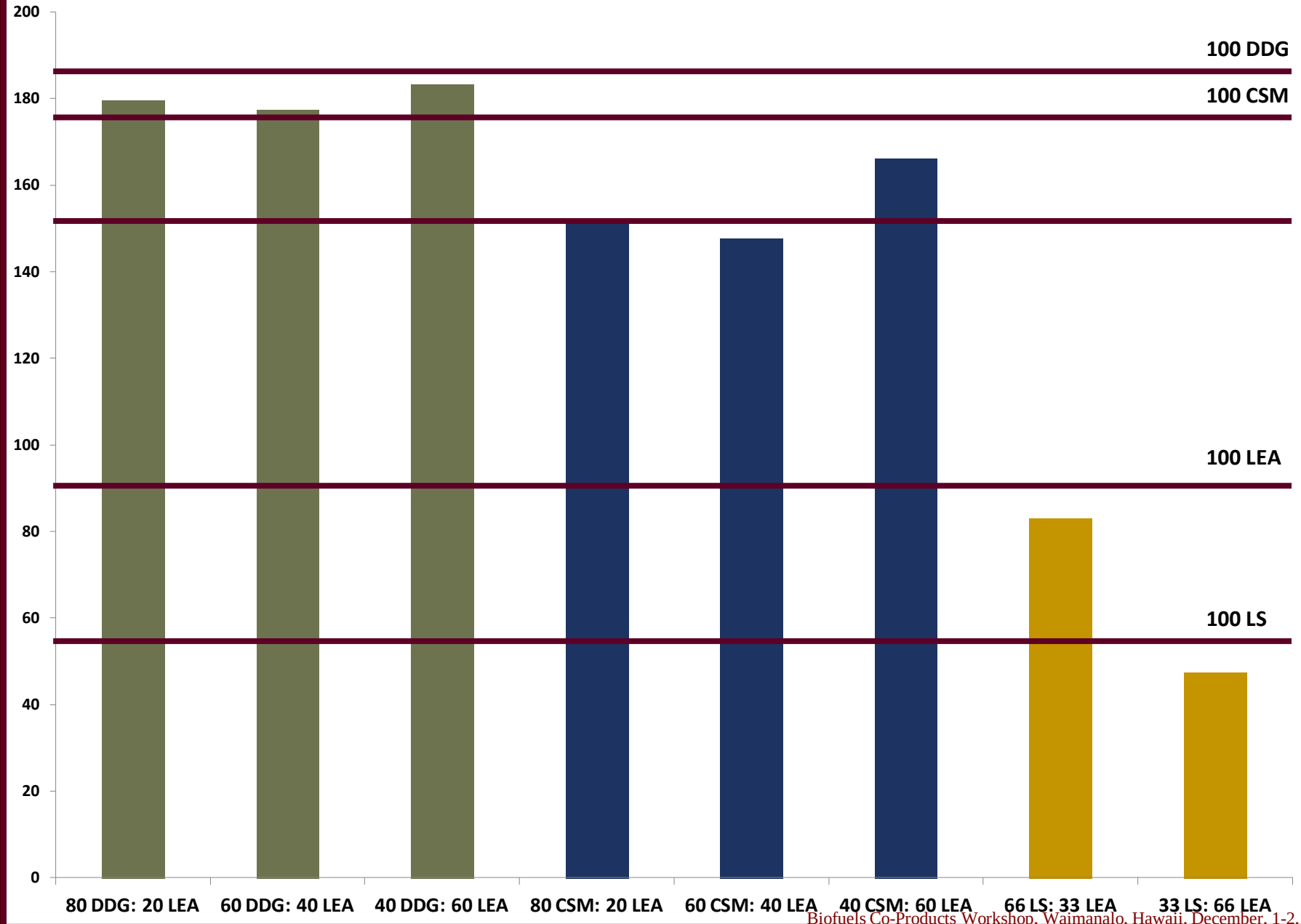
Supplement Composition

	Dried Distillers'	Lipid Extracted Algae
1	100	0
2	80	20
3	60	40
4	40	60
	Cottonseed Meal	**Lipid Extracted Algae**
5	100	0
6	80	20
7	60	40
8	40	60
	Liquid Supplement	**Lipid Extracted Algae**
9	100	0
10	66	33
11	33	66
12	0	100

Time required for complete consumption



Grams consumed per minute



Summary

- Lipid extracted algae was not as palatable as distiller's grains or cottonseed meal when offered alone.
- Lipid extracted algae when mixed with distillers' grains or cottonseed meal at levels of up to 60% did not negatively affect the pattern of supplement consumption in beef cattle.
- These results are encouraging for the use of lipid extracted algae in grazing cattle supplements and suggest the possibility of additional value in supplements containing lipid extracted algae.

Summary

- Data to date indicate that defatted algae can replace either soybean or fish meal in marine fish and shrimp diets.
- Data to date indicate that defatted algae can be use as a supplement in cattle diets.

HOWEVER ---

AgriLIFE RESEARCH
Texas A&M System

Concerns

- Protein level is less in defatted algae than whole algae.
- High divalent cation (e.g. Fe, Al) levels in defatted algae.

AgriLIFE RESEARCH
Texas A&M System

Preliminary Algae Co-Product Value to Fish, Shrimp, Cattle

- Assuming algae co-product protein level equal to protein level of ingredient being replaced ---
- Fish meal in marine fish and shrimp diets: $1,200 to $1,400/m.t.
- Soybean meal in marine fish and shrimp diets: $400 to $440/m.t.
- DDGS meal in cattle: $300 to $330/m.t.

Acknowledgements

- Funded in part by US Department of Energy under contract DE-EE0003046 awarded to the National Alliance for Advance Biofuels and Bioproducts and by Texas AgriLife Research, Texas A&M University System
- Staffs of the Texas AgriLife Research Mariculture Laboratory at Port Aransas and Departments of Animal Science and Wildlife and Fisheries Sciences, Texas A&M University System

National Alliance For Advanced Biofuels and Bio-products

AgriLIFE RESEARCH Texas A&M System

U.S. DEPARTMENT OF ENERGY

From Texas A&M University

Thank You!!!!!

AgriLIFE RESEARCH
Texas A&M System