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Depuration and Slaughter Techniques to Optimize Atlantic Salmon Product Quality from Land-Based Closed Containment Systems

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Aquaculture Innovation Workshop #4
Comox, British Columbia

Introduction

- Increased use of recirculating aquaculture systems (RAS) to culture aquatic species, including Atlantic salmon

- Many advantages of RAS, but one drawback
  - Bioaccumulation of off-flavor compounds within fish flesh
  - Create an earthy or musty taste

- Caused by microbial metabolites produced by actinomycetes and cyanobacteria
  - 2-Methylisoborneol (MIB)
  - Geosmin

Introduction

- Off-flavor not reported for A. salmon cultured in ocean net pens but reported in A. salmon caught in freshwater rivers

- For RAS to be viable technology, methods for off-flavor removal are necessary

- Can be effectively accomplished using depuration process
  - Fish off feed
  - Clean/ biofilm-free system water
  - Flow Through or Partial Reuse System

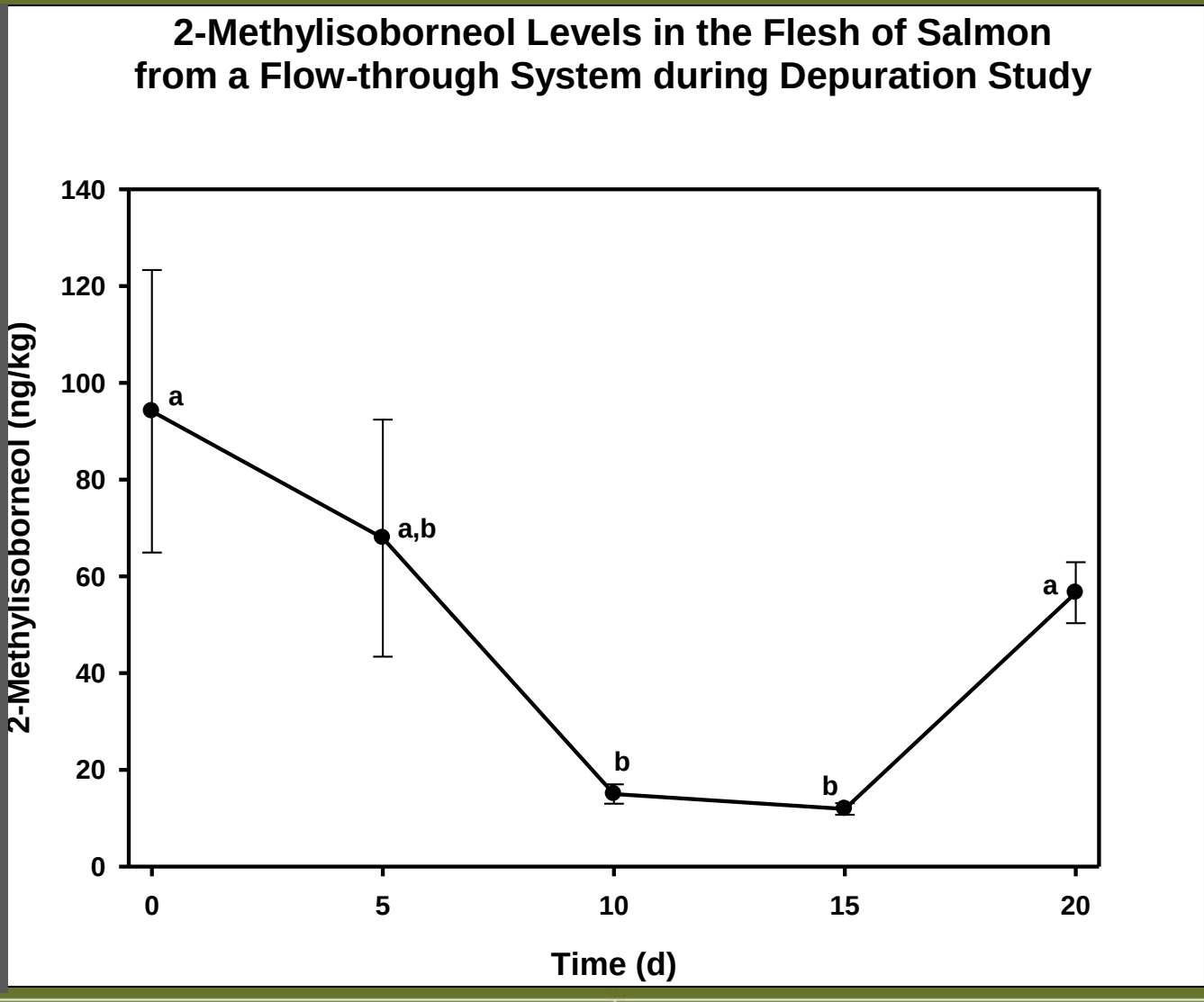
- Ozone used at non-disinfecting dose did not remove off-flavor from trout from low exchange RAS (Schrader et al., 2010)

Introduction

- Burr et al. 2012. Impact of depuration of earthy-musty off-flavors on fillet quality of Atlantic salmon cultured in a recirculating aquaculture system. Aquacultural Engineering.
- Determined approximate amount of time and conditions for optimal depuration of A. salmon cultured in RAS
- Salmon cultured in RAS with 97% recycle rate (flow basis)

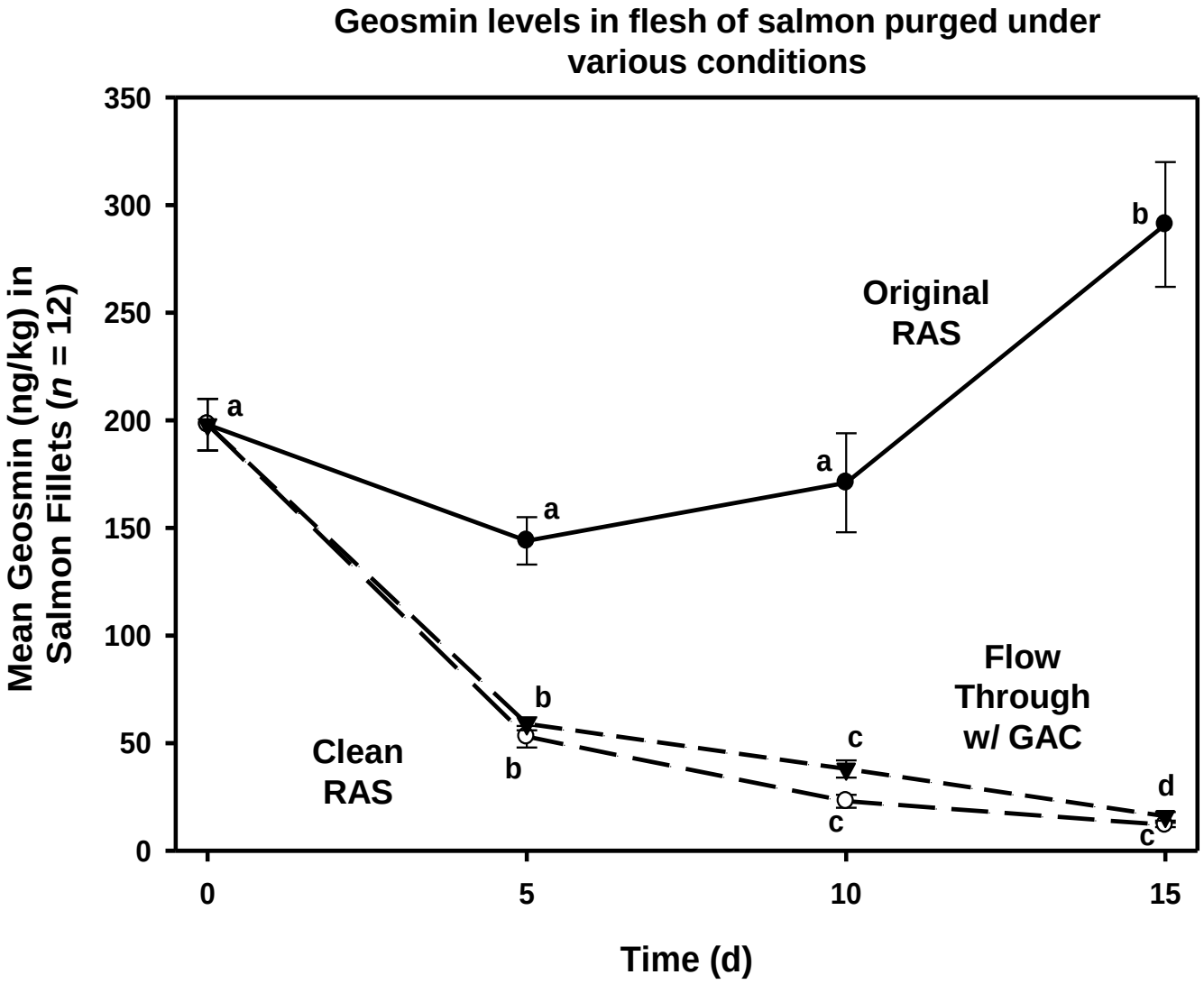
Burr et al. 2012 Results

- Cited from Wolters et al., 2011. Weight Loss and Fillet Quality Characteristics of Atlantic Salmon after Purging for 5, 10, 15 or 20 days. Aquaculture Innovation Workshop I, Shepherdstown, WV.
- Optimal purge time = 10-15 days



Burr et al. 2012 Results

- Cited from Wolters et al., 2011.
- Salmon purged more effectively in geosmin/MIB-free RAS and flow through system

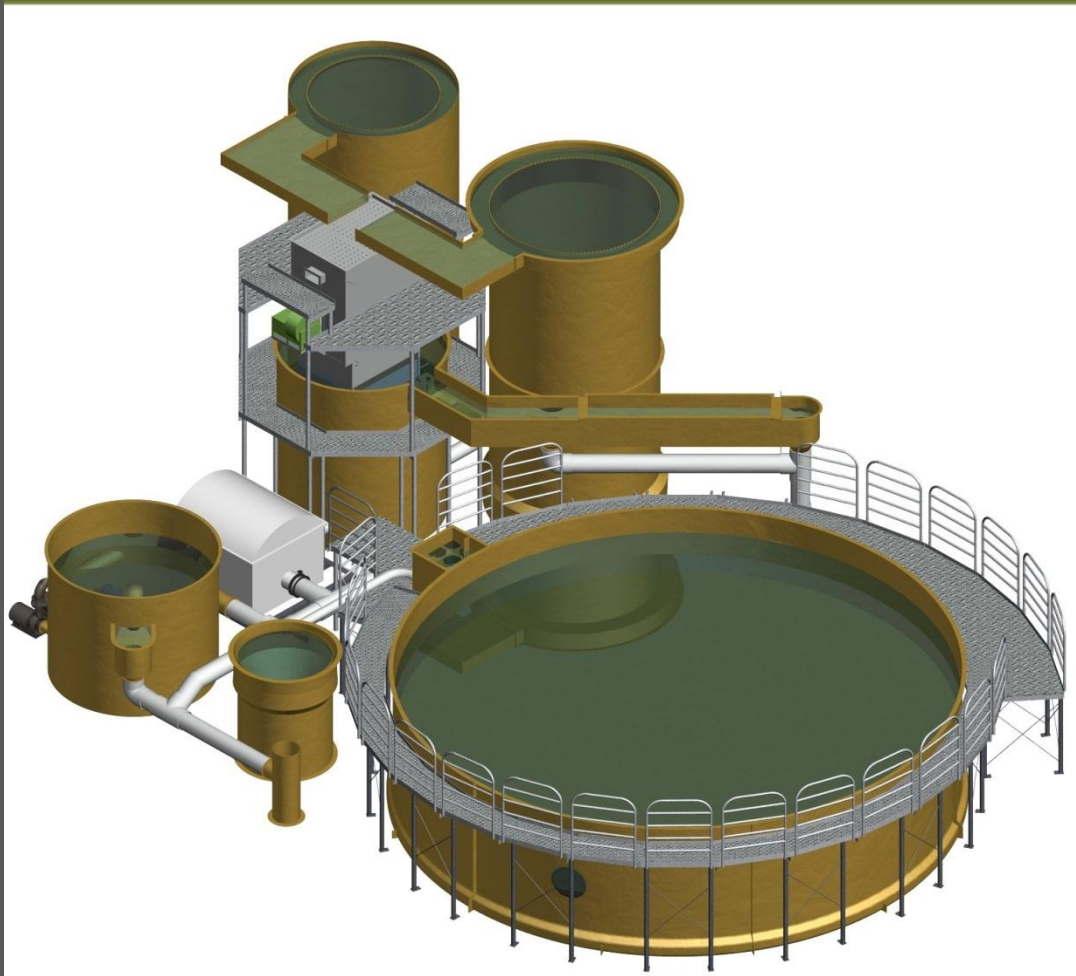


Burr et al. 2012 Conclusions

- 10-15 days optimal depuration time
- Taking salmon off feed prior to harvest shouldn't be only method
- Recommend fish relocation to biofilm-free depuration system
- Fillet color not impacted during depuration
- Use of granular activated carbon to treat influent of depuration system appears to be beneficial

150 m^3 Commercial Scale Grow-out RAS

- A. salmon used for depuration and fillet quality studies harvested from commercial scale RAS
- Recycle Flow
  - 99.75% (flow basis)
  - 1500 gpm recycle
- Makeup Flow
  - < 5 gpm
- Fish Density - 50-60 kg/m^3
- Feed Loading Rate –
  - 6-7 kg feed/ m^3 makeup flow/day



Freshwater Institute Depuration Study Methods

- Twelve 0.5 m^3 circular single drain tanks
- Prior to stocking salmon for depuration - equal numbers of rainbow trout cultured in tanks to establish biofilm
- Partial reuse systems operated at appx. 92% recycle
  - 26 gpm recycle flow
  - 2 gpm makeup flow
  - Hydraulic Retention Time > 1 Hr
- Recycle water pumped from within tank through CO_2 stripping column

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0.5 m^3 Experimental Partial Reuse Systems

Salmon Depuration Experimental Design

Experimental Tanks per Treatment	Granular Activated Carbon (GAC)	Hydrogen Peroxide
3	✓	✓
3	✓	
3		✓
3		

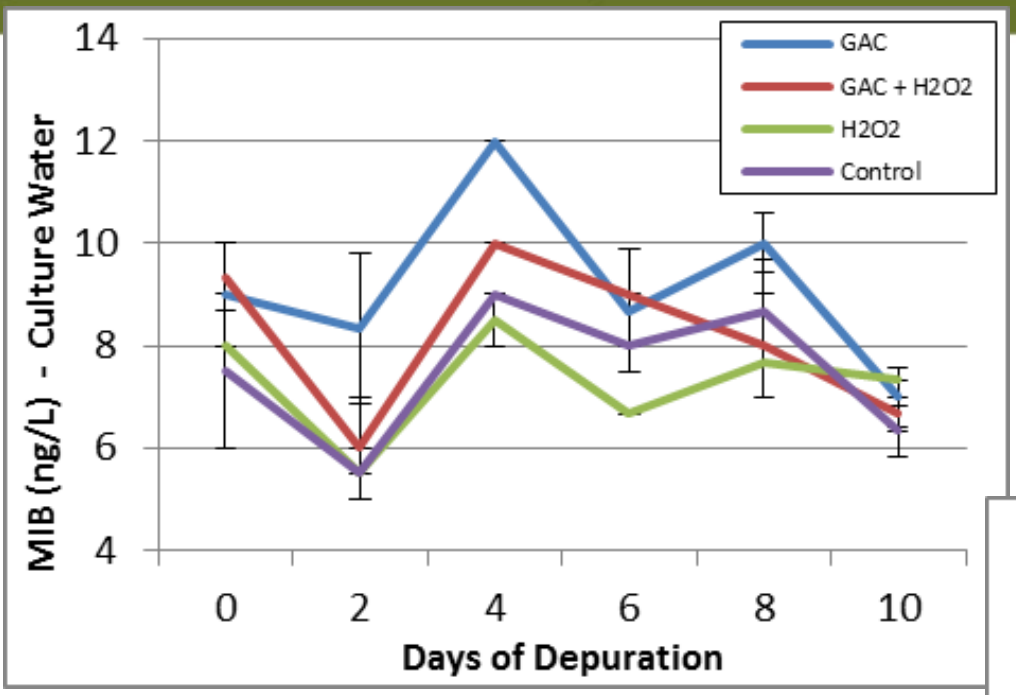
Granular Activated Carbon Filtration

- All makeup water entering six tanks assigned GAC treatment passed through GAC filter

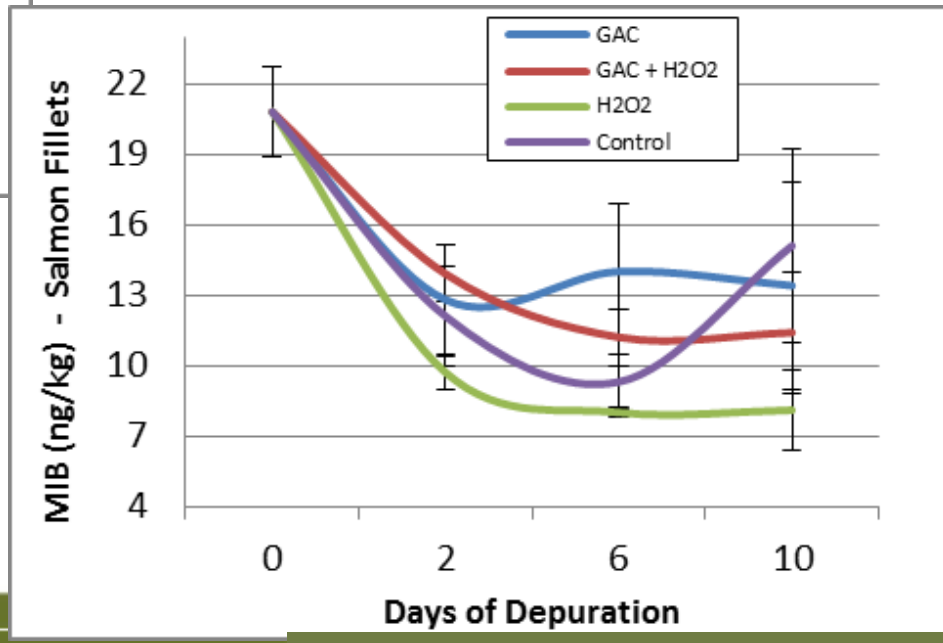
Depuration Study Sampling Methods

- Fillet samples
  - Trial 1 - Days 0, 2, 6, 10
  - Trial 2 - Days 0, 1, 2, 5
- Water and biofilm samples
  - Trial 1 - Days 0, 2, 4, 6, 8, 10
  - Trial 2 - Days 0, 1, 2, 5
- All samples tested by Kevin Schrader, Microbiologist at University of Mississippi for off-flavor compounds – geosmin and MIB

MIB in Culture Water and Salmon Fillets

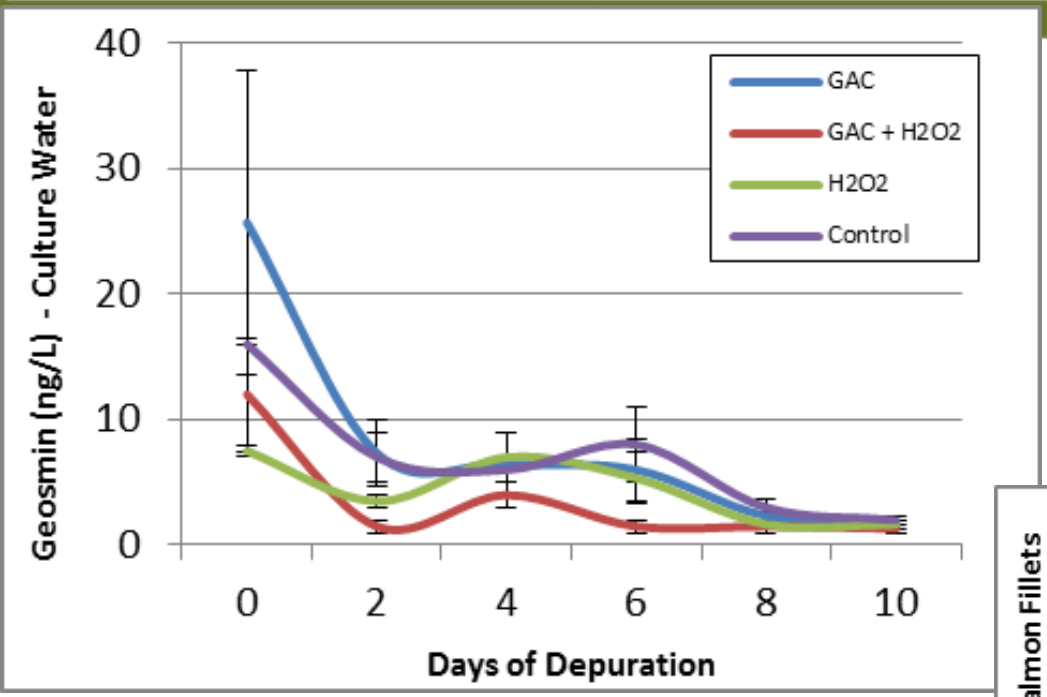


- MIB concentrations very low to begin in culture water and fillets
- MIB concentrations in water unaffected by treatment or time

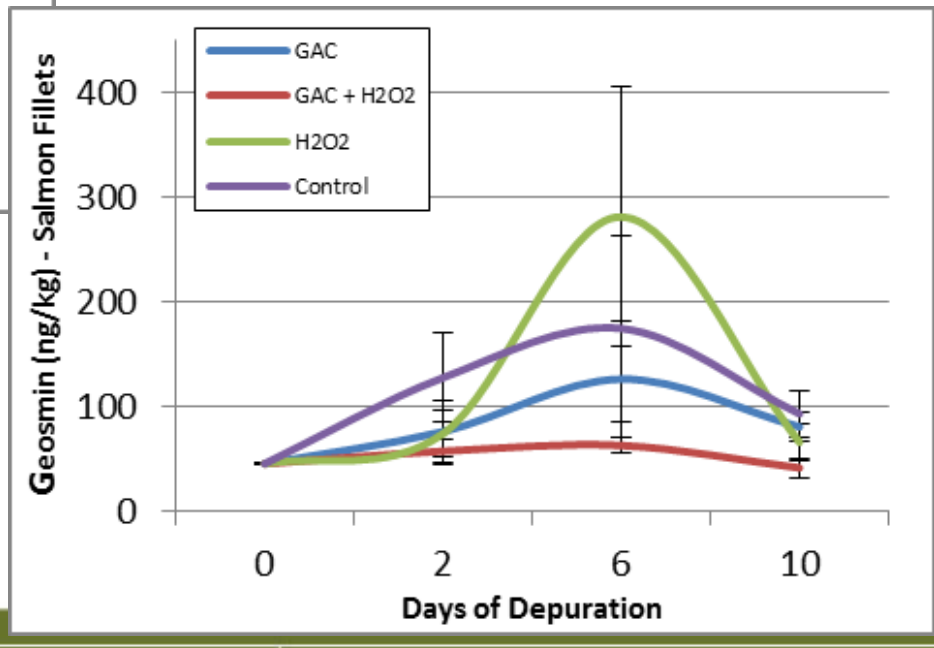


- Depuration occurred for all treatments
- Lowest MIB in salmon harvested from H_2O_2 and GAC + H_2O_2 treated systems

Geosmin in Culture Water & Salmon Fillets



- Geosmin concentrations in water declined over 10-day period



- Geosmin concentrations in fillets increased for all treatments except GAC + H_2O_2
- Increase in off-flavor would not be expected in clean, biofilm-free depuration system

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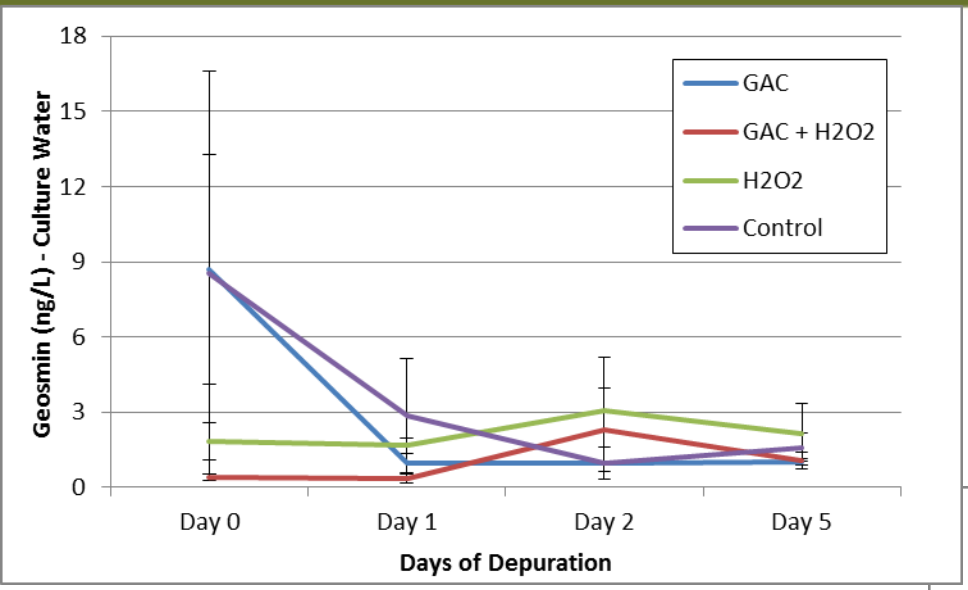
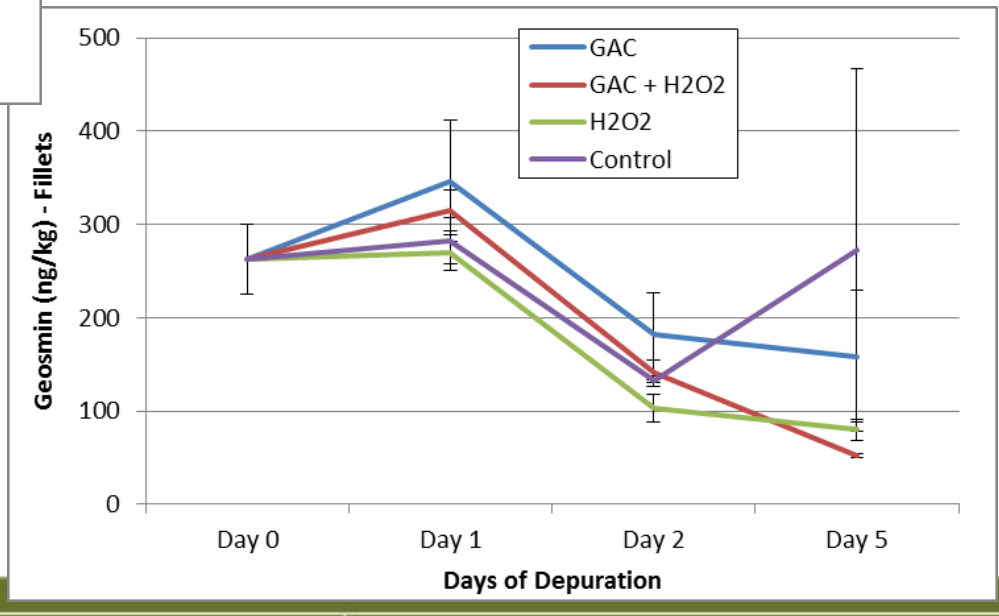
Geosmin in Culture Water & Salmon Fillets Trial 2



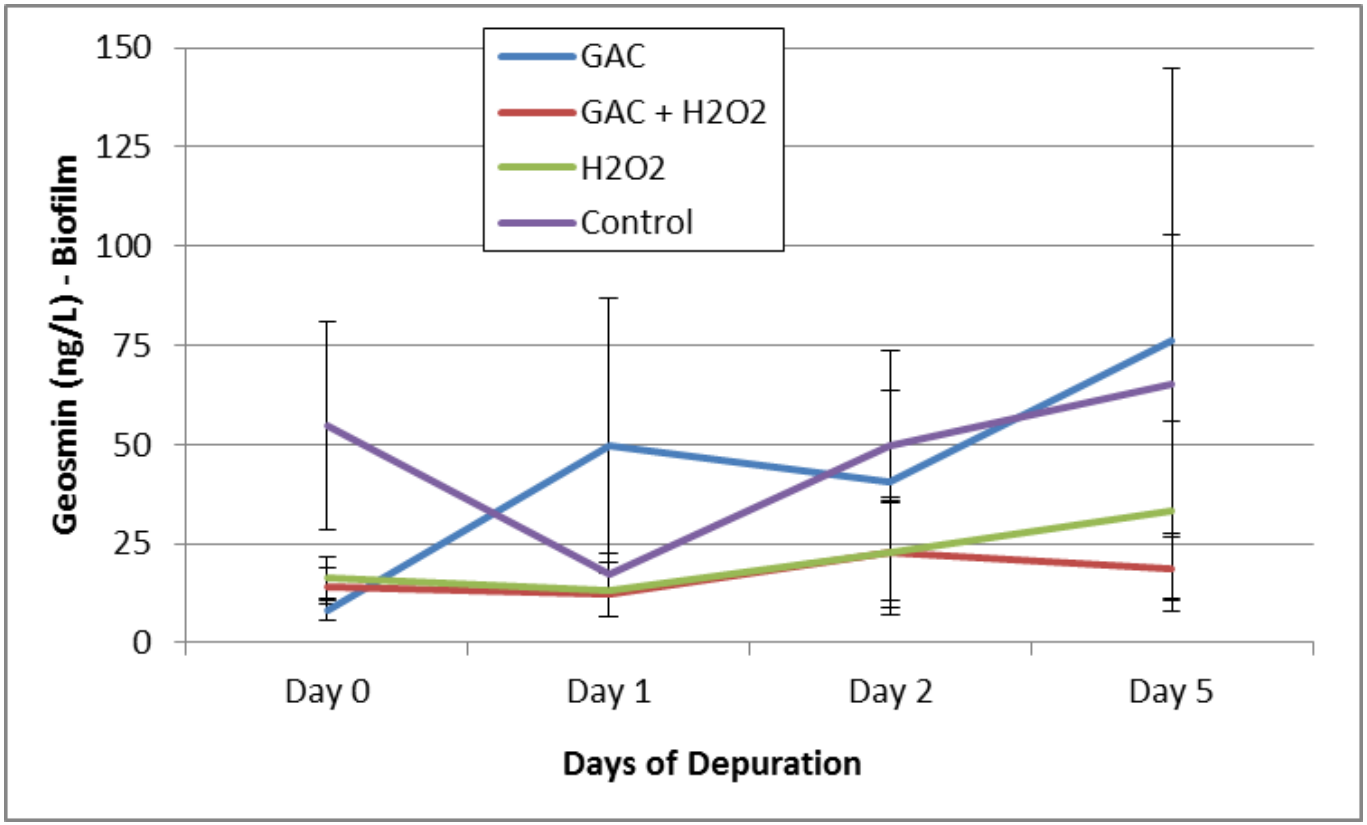
- Treatment with peroxide created lower levels of geosmin to begin!!

- Lower levels of geosmin in culture water of peroxide treated systems resulted in lower geosmin in fillets!!



Geosmin in Biofilm Trial 2

- Similar effect of peroxide on biofilm on tank walls!

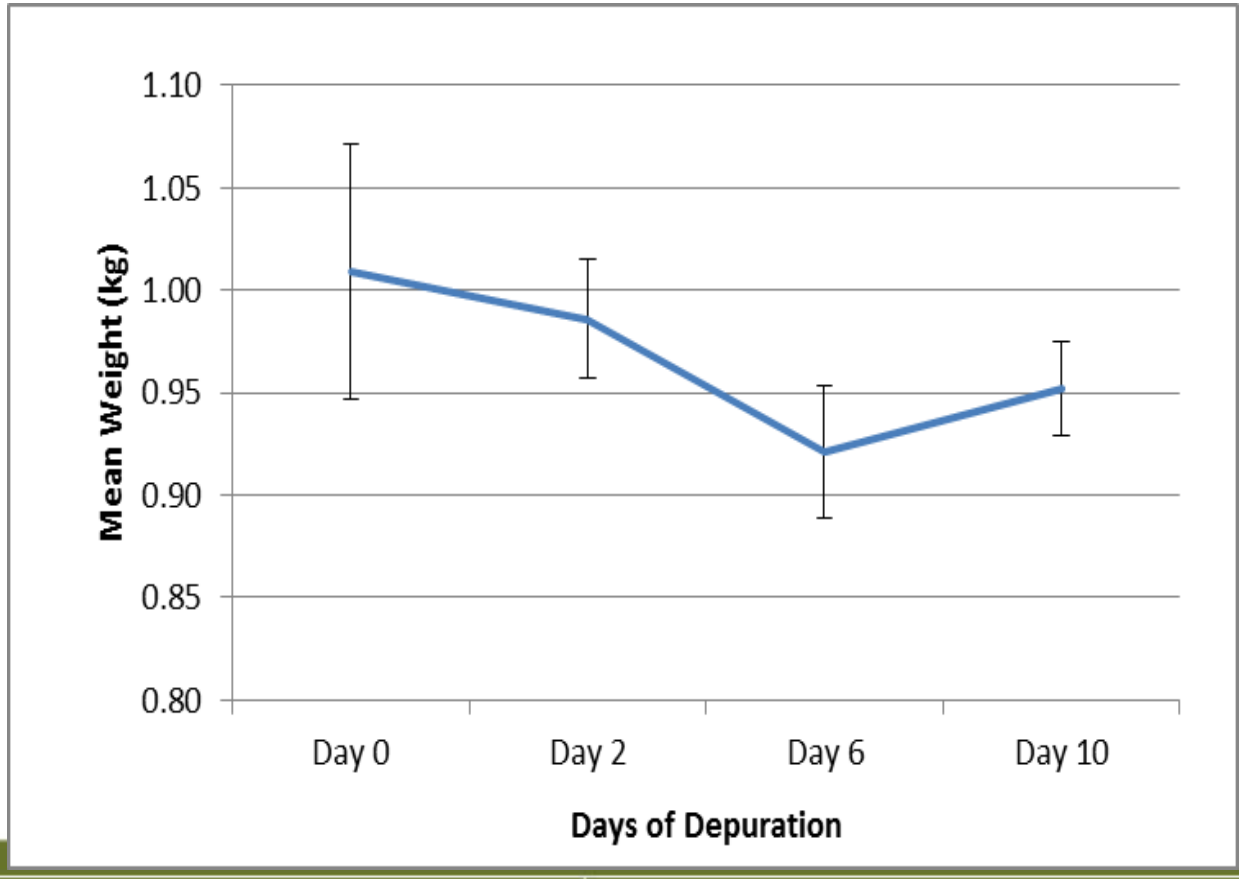


Depuration Results

- Results indicated 4-5% body weight lost from Day 0 to 10

- Later results showed fillet yield was not impacted by 10-day depuration

- Reducing depuration time from 10 days could be beneficial if off-flavor sufficiently reduced



Depuration Results

- Studies conducted with systems treated with various methods, but not brushed/ cleaned prior to stocking for depuration to simulate worst case industry scenario
- Thorough pre-cleaning is critical so that depuration systems are clean/ biofilm-free to begin
- Off-flavor concentrations in fillets can increase in "dirty" depuration systems with biofilm on walls of unit processes
- GAC combined with H_2O_2 disinfection appears to be best treatment option
- H_2O_2 disinfection alone was also effective

Depuration Results

- Communication with other industry personnel indicates that carbon dioxide stripping columns can harbor off-flavor producing bacteria

- Depuration time could be reduced from 10 days if:
  - starting with clean/biofilm free systems
  - bypass carbon dioxide stripping columns or using columns with no packing
  - Using fish with inherently low initial off-flavor concentrations

Promising News

- Marketing research using optimal depuration techniques indicates success!

- Blind taste tests of 2 panels of seafood professionals in Seattle indicated preference for Freshwater Institute salmon cultured in RAS and depurated 10 days vs. commercially available ocean-raised A. salmon

  - Cooked flavor
  - Cooked smell
  - Cooked texture

Promising News

"It was the first closed contained fish which we've sampled that not only tasted great and entirely lacked any muddy, earthy, plastic, or metallic taste whatsoever. So whatever Steve S. and his team are doing with respect to recirculation systems, feed formulae, depuration, etc., the rest of the closed contained fish farming community should take note because he appears to have nailed the recipe."

-Dane Chauvel, Organic Ocean

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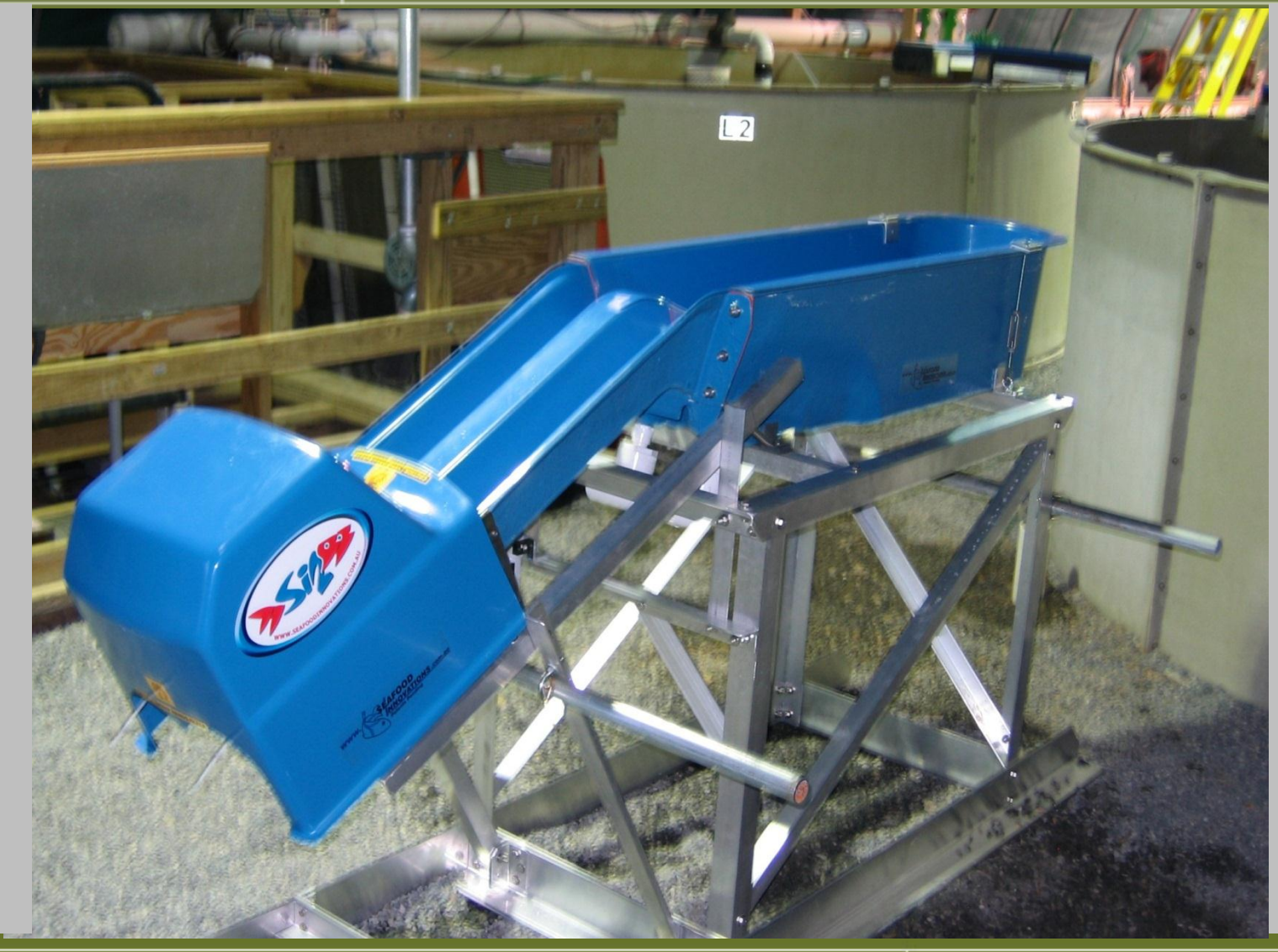
Evaluation of Humane Slaughter Techniques

SI-2 Stunner Technology



SI-2 Stunner Technology

Fish Automatically Triggers Piston

Pneumatic Piston Design

Humane Slaughter Techniques Study Methods

- Four techniques compared using depurated and non-depurated salmon from grow-out:
  1. Humane Stunner Technology with bleeding
  2. Humane Stunner Technology without bleeding
  3. Carbon Dioxide and Ice Slurry with bleeding
  4. Carbon Dioxide and Ice Slurry without bleeding

- Six salmon randomly selected and euthanized using each slaughter technique
  - Males and obviously mature fish excluded
  - 4-5 kg fish targeted

- For groups assigned bleeding, gills manually cut just after euthanasia

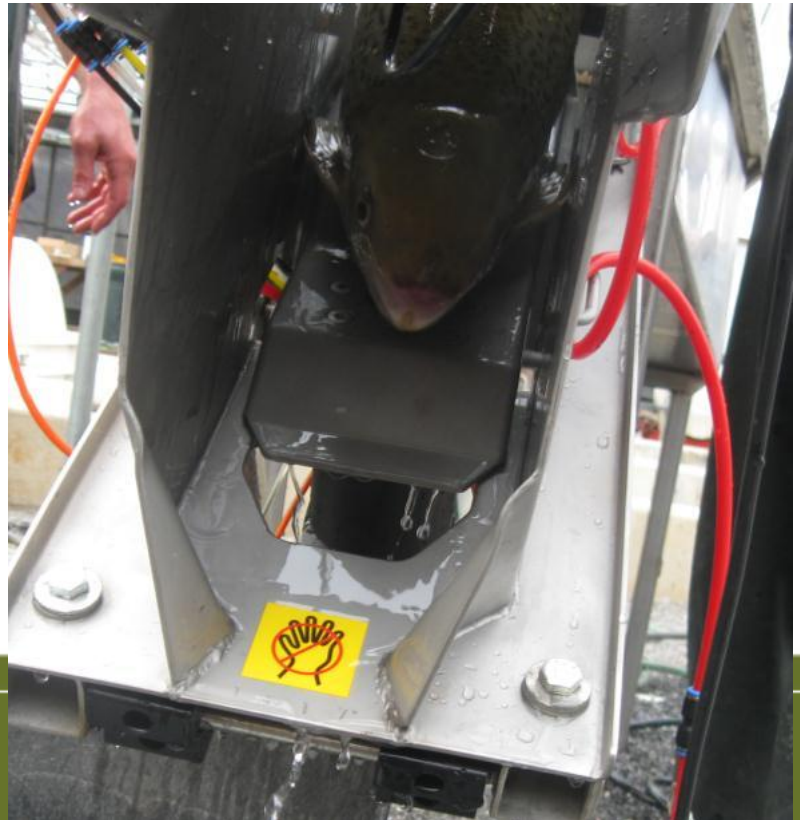
Fillet Quality Measurements

- Length/ whole Body Weight
- Fillet weights and yields
- Gonadosomatic Index
- Fillet temperature, pH
- Fillet texture and color
- Proximate analysis and fatty acids

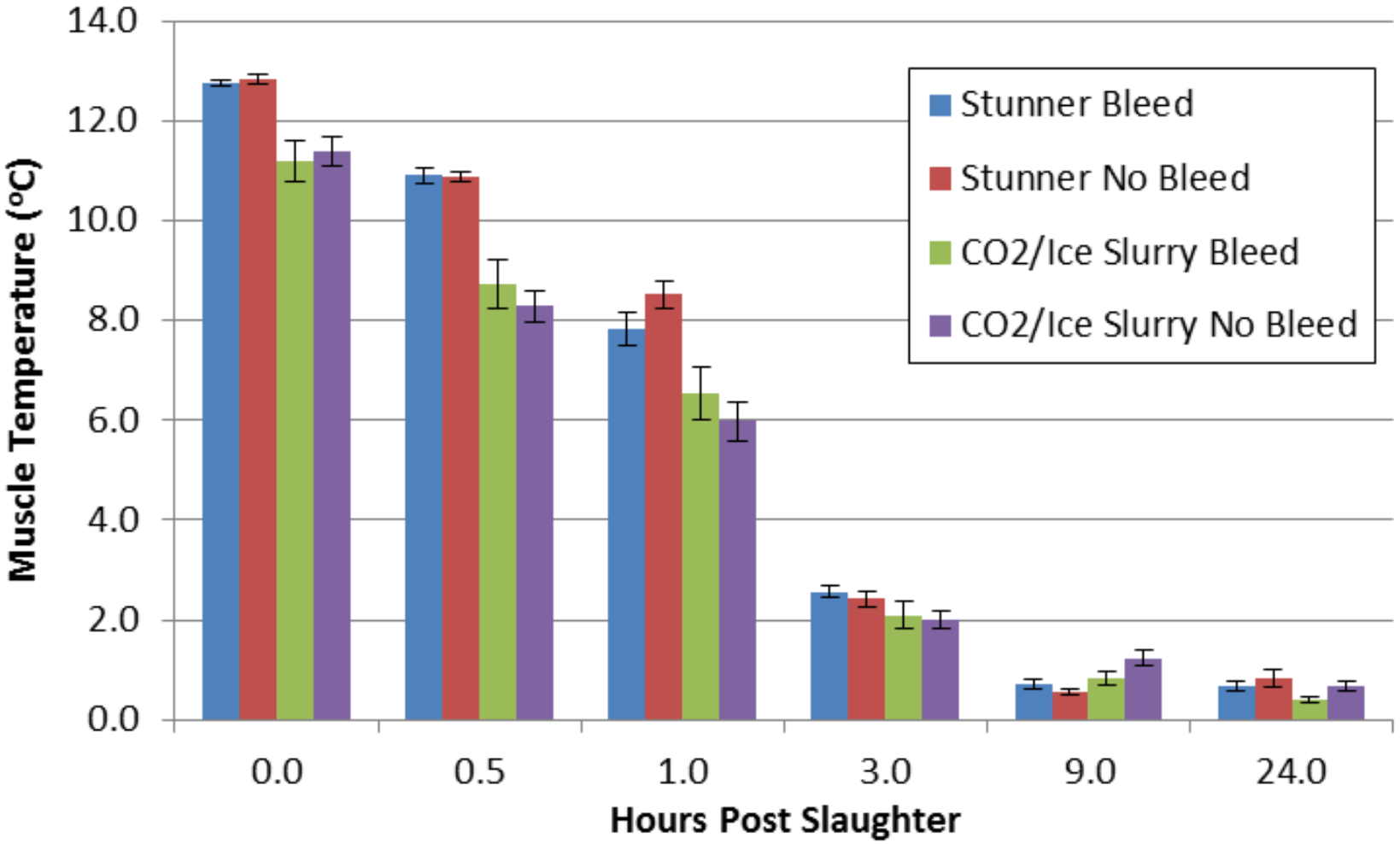
Post-Harvest Slaughter

Rapid & Humane

- Percussive Stunning
  - MODEL SI-7 Stunner (Seafood Innovations)

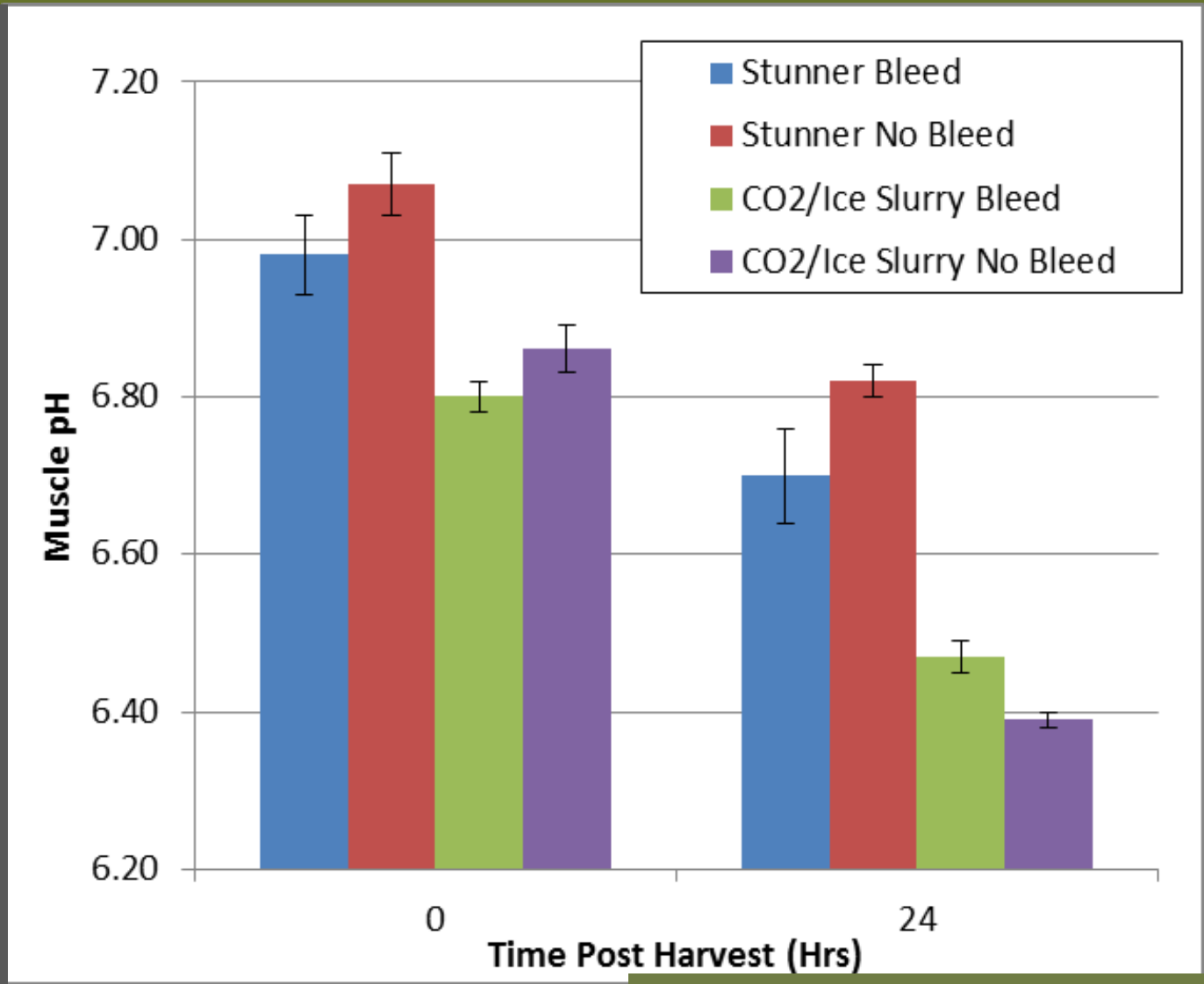


Fillet Quality - Temperature



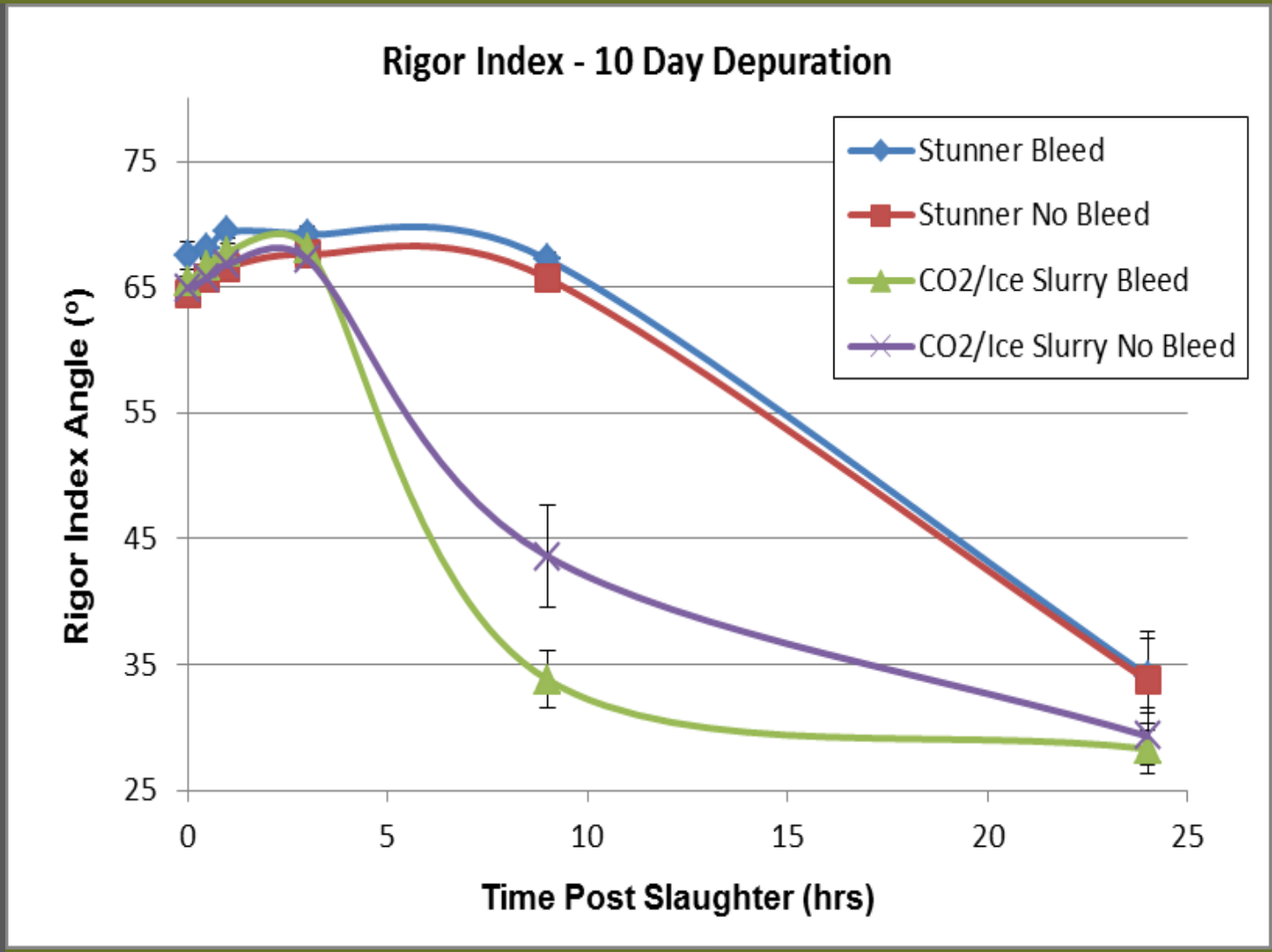
Fillet Quality - pH

- Salmon euthanized using humane stunner technology had greater and less fluctuating fillet pH levels (P <0.05)
- Indicative of less struggle and stress during slaughter
- Generally leads to improved fillet quality



Fillet Quality – Rigor Onset

- Rigor onset significantly slower (5-7 hrs +) for salmon euthanized using humane slaughter technology
- Slower rigor onset generally correlated with improved fillet quality and provides time for pre-rigor processing

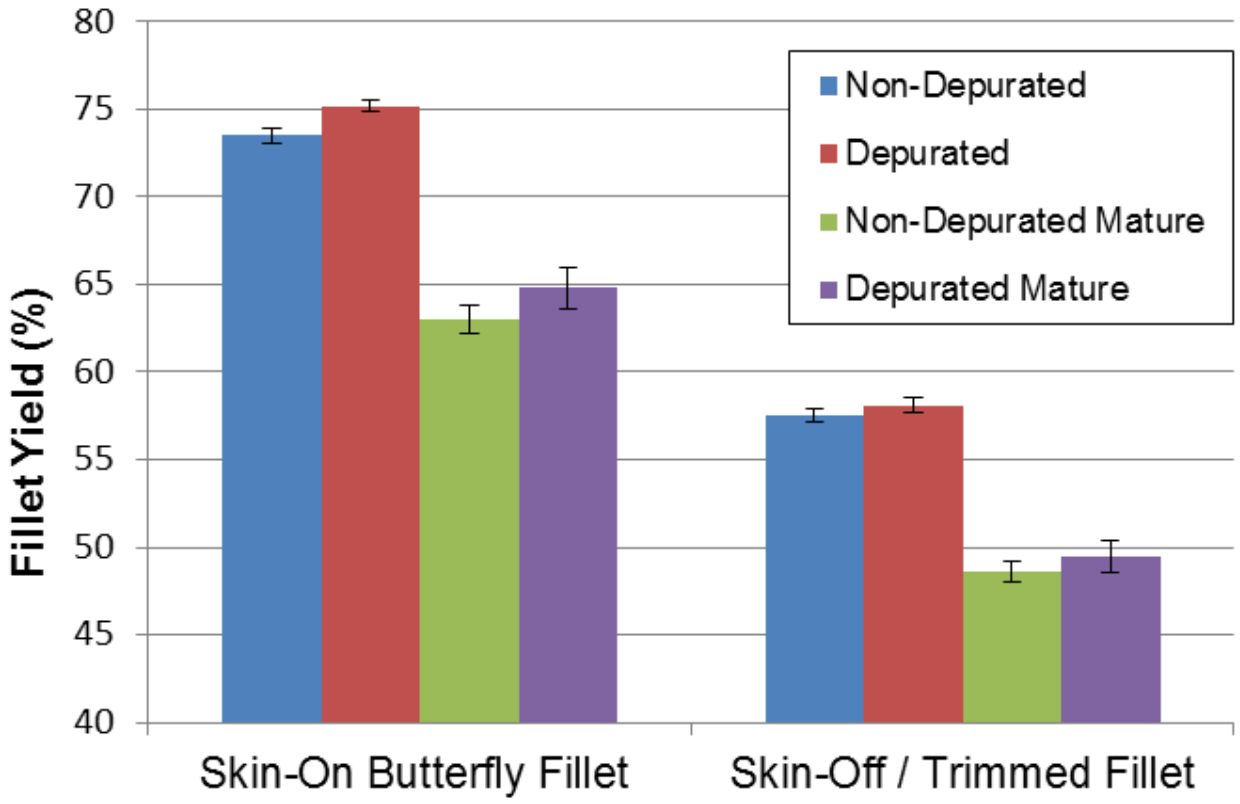


Fillet Quality (Depurated vs. Non-Depurated)

- No significant difference in fillet color between non-depurated and 10-day depurated salmon
- No difference in fillet yield
- No difference in percentage fat of fillet measured during proximate analysis
- No difference in fatty acid content

Color Score on Salmo ™ Fan 28-30

Atlantic Salmon Fillet Yield



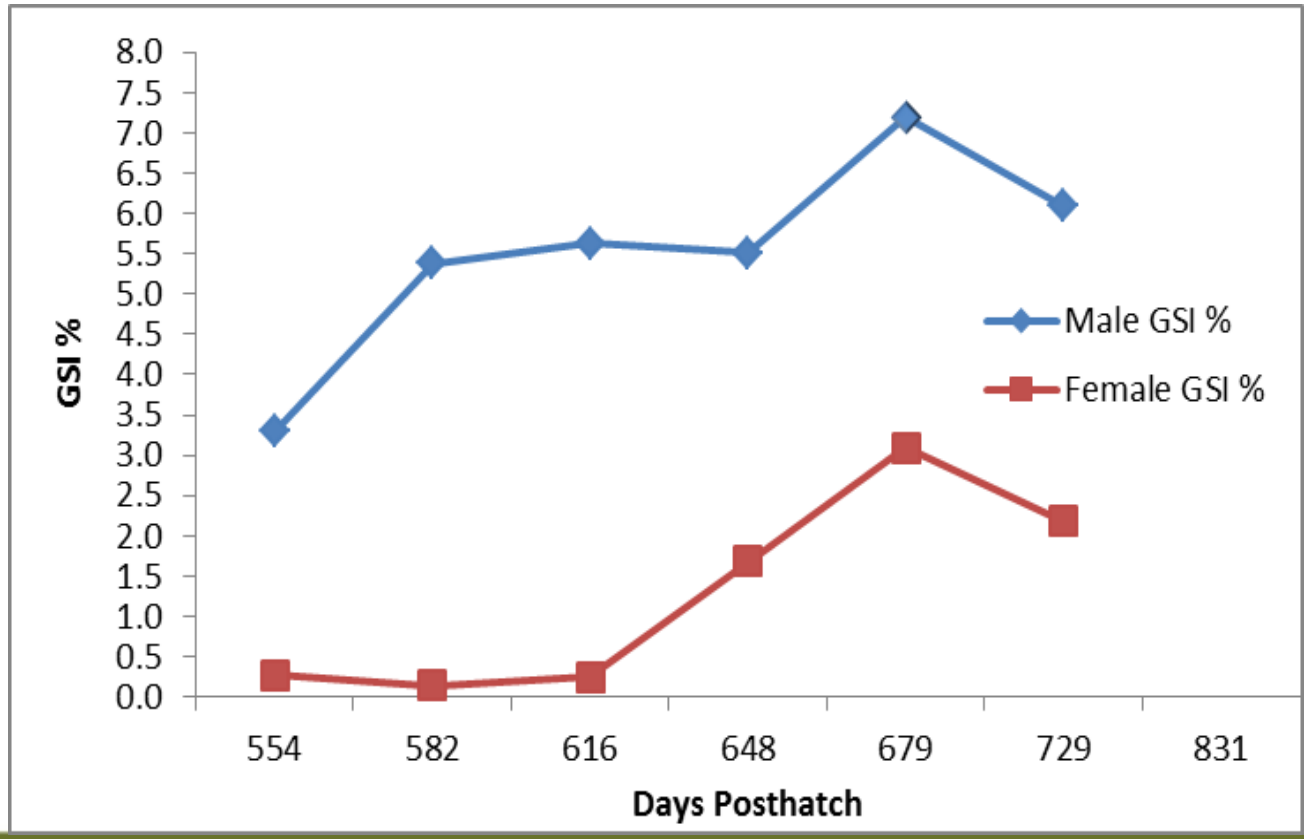
Other Product Quality News and Considerations

- Gonadosomatic Index indicates percent body weight makeup of reproductive organs

- Males matured much earlier

- Females began to mature - 20-21 months of age

- It is imperative that early maturation is avoided to maintain color and fillet quality

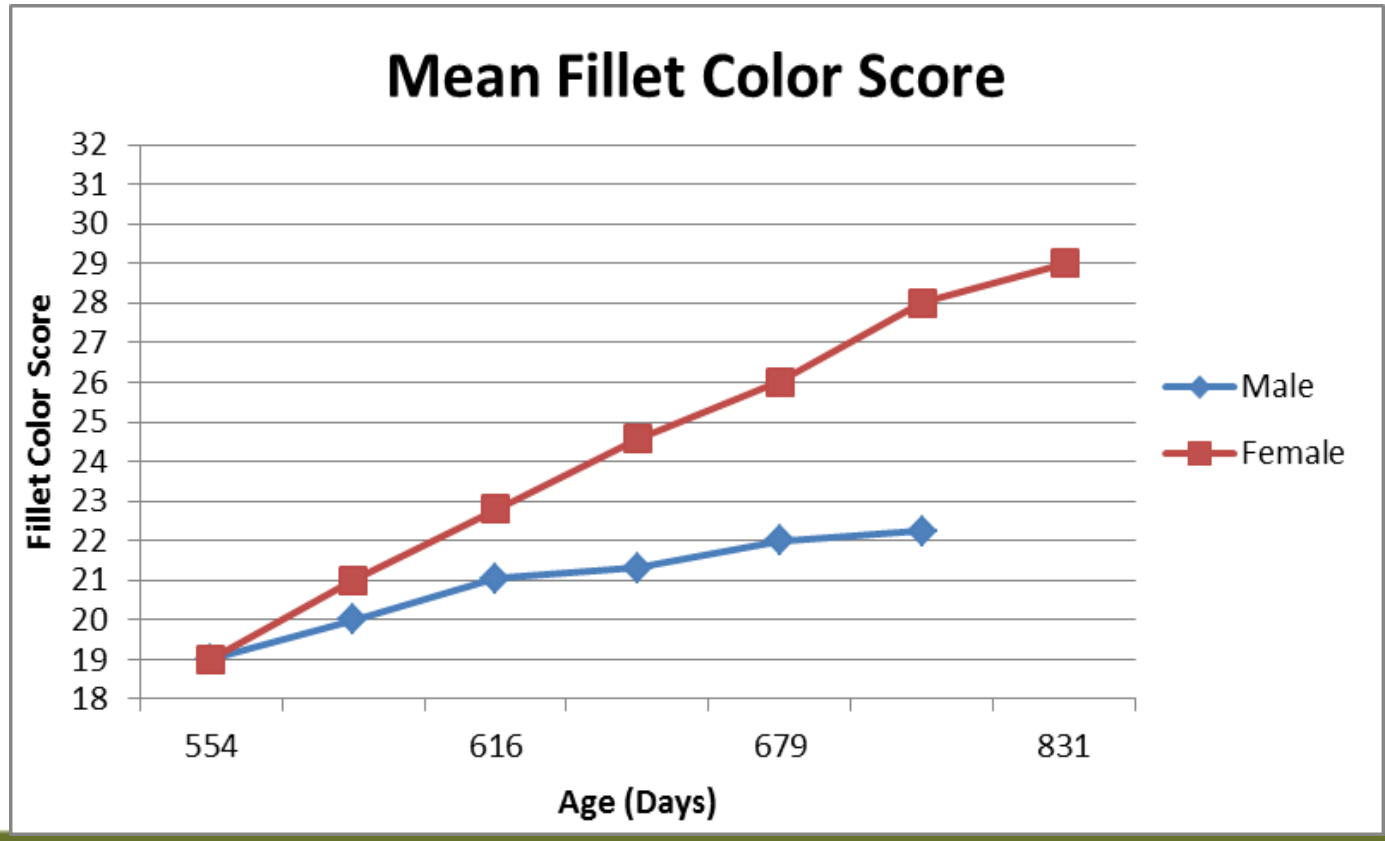


Other Product Quality News and Considerations

- Fillet color increases steadily with time when feeding a diet containing astaxanthin pigment. It is not instantaneous!!

- Feed contained 30 ppm

- Lighter, less optimal fillet color of male salmon



Conclusions

- Humane stunning technology improves fillet attributes
  - Less struggle = lower ATP use and less lactic acid
  - Less fluctuation of flesh pH
  - Slower onset to rigor

- Bleeding did not impact most fillet quality parameters
  - Texture (firmness) was significantly greater for non-bled fish slaughtered using humane stunner
  - Processor (Dr. Brett Kenney) commented that bled fish much cleaner to work with and likely less potential for bacterial accumulation/ spoilage

- Technology commercially available and being used by industry

Conclusions

- Fillet color is unaffected after 10 days depuration
- Fillet yield, fatty acid concentrations, and fat content unaffected after 10 days depuration
- Maturing fish had significantly reduced fillet yield and fat content

Acknowledgements

- Research supported by Tides Canada and the Gordon Betty Moore Foundation.

- All experimental protocols were in compliance with Animal Welfare Act (9CFR) and have been approved by the Freshwater Institute Animal Care and Use Committee.

- Special thanks to Justin Sabrio, Tre Kidwell, Phil Backover, and Karen Schroyer for technical assistance and to Vera Anthony and Susan Slider for help with processing and fillet attribute analysis.