Wild, farmed and growth-enhanced transgenic coho salmon (market-size) were compared, regarding their body composition and nutritional value. All treatments showed highest lipid levels in the ventral frontal sections and lowest in the tail (p ≤ 0.05). Overall wild fish showed lower lipid levels and firmer values in the tail sections (p ≤ 0.05). The insertion of the growth hormone gene affected lipid deposition, texture and color, since transgenic fish showed firmer texture than farmed and similar lipid contents even when fed a high-energy diet. L*, a* and b* values were similar for wild and transgenic coho in most of the body zones. Fillet mineral and amino acid profiles were similar across all groups. No differences were observed in flavor between farmed and wild coho, while panelists preferred the appearance of farmed, when compared to transgenic coho.
ACKNOWLEDGEMENTS

First of all, I would like to thank God for allowing me the opportunity to come to Virginia Tech and complete my masters and now my Ph.D. Without his power and love I would have never been able to accomplish both goals. His words gave me strength and courage through all this process: I can do all things through Him who strengthens me (Philippians 4:13).

I want to thank my advisor, Dr. George Flick, Jr. for helping me in these three years and being not only a guide but a wonderful human being whom I respect and admire.
I also want to thank my Master’s advisor Dr. Susan Duncan for helping me through my masters and Ph.D, and also for being always concerned and caring.
Dr. Sean O’Keefe for always being available to help solve all my problems in the chemistry area and make everything look so easy and simple.
I want to thank Dr. Steven Craig and Dr. Ewen McLean for showing me how fun it is to work with fish and helping me constantly in the lab and during the writing process, but overall for being not only mentors but friends.
I would also like to thank Kim, Harriet, Dr. Wang, Scott, John, Terry and Laura. You are the backbone of the Food Science Department and without your help we would be lost. Also big thanks to Rob at the Aquaculture Center for taking care of my fish when I was not able to and Wendy for her valuable help.
I want to thank all my wonderful friends, who heard me complain and helped me relax, work and have fun: Marleen, Bridgett, Jaehee, Kannapha, Janet, Stephanie, Jenny, Mary Dean, Leigh Ann and all my friends back home who supported me with emails and phone calls.
Very special thanks to Fletcher Arritt, for being my best friend, confident and support. He did not only help me with my research but helped me laugh and enjoy every minute I spent here in Blacksburg.
I want to finally thank my parents and sisters, Monica and Angela for believing in me and helping me through all these years with their love and encouragement. I owe this to you.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title Page</td>
<td>i</td>
</tr>
<tr>
<td>Abstract</td>
<td>ii</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>iv</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>v</td>
</tr>
<tr>
<td>List of Figures</td>
<td>xi</td>
</tr>
<tr>
<td>List of Tables</td>
<td>xii</td>
</tr>
</tbody>
</table>

## CHAPTER I
### INTRODUCTION

## CHAPTER II
### LITERATURE REVIEW

2.1 Aquaculture Status in the U.S.

2.1.1 Biotechnology in Aquaculture

2.2 Fish Quality

2.3 Proximate Composition of Fish

2.4 Impact of Nutrition in Farmed Fish Quality

2.4.1 Dietary Protein

2.4.2 Dietary Carbohydrate

2.4.3 Dietary Lipid

2.5 Fatty Acid Profile

2.6 Lipid Oxidation

2.7 Sensory Properties of Fish

2.7.1 Flavor and Aroma

2.7.2 Color

2.7.3 Texture
CHAPTER VI
VARIATIONS IN CHEMICAL, PHYSICAL AND SENSORIAL PROPERTIES OF WILD AND CULTIVATED SOUTHERN FLOUNDER
(Paralichthys lethostigma) ................................................................. 97
Abstract ...................................................................................... 98
Introduction ................................................................................. 99
Materials and Methods ............................................................... 100
Animals ...................................................................................... 100
Compositional Analyses .............................................................. 100
Color .......................................................................................... 100
Minerals ..................................................................................... 100
Firmness ..................................................................................... 101
Sensory Analysis ........................................................................ 101
Fatty Acid Profile ....................................................................... 101
Statistical Analysis ..................................................................... 102
Results and Discussion ............................................................... 103
Conclusions .............................................................................. 106
Acknowledgements .................................................................... 106
References .................................................................................. 107

CHAPTER VII
CHEMICAL, PHYSICAL AND SENSORIAL DIFFERENCES IN FARmed
SOUTHERN FLOUNDER (Paralichthys lethostigma) FED COMMERCIAL
OR CRAB MEAL-SUPPLEMENTED DIETS ............................................ 115
Abstract ...................................................................................... 116
Introduction ................................................................................. 117
Materials and Methods ............................................................... 118
Animals ...................................................................................... 118
Diets and Feeding ....................................................................... 118
Compositional Analyses .............................................................. 118
CHAPTER VIII
COMPOSITIONAL ANALYSES AND NUTRITIVE PROPERTIES OF MARKET-SIZE WILD, FARmed AND GENETICALLY MODIFIED COHO SALMON (Oncorhynchus kisutch) .......................................................... 131
Abstract ................................................................................................. 132
Introduction .......................................................................................... 133
Materials and Methods ......................................................................... 135
   Animals .............................................................................................. 135
   Sample Preparation ........................................................................... 136
   Compositional Analyses and Firmness ................................................. 136
   Color ................................................................................................. 136
   Amino Acid Profiles .......................................................................... 136
   Minerals ............................................................................................ 136
   Sensory Analyses ............................................................................. 137
   Statistical Analysis .......................................................................... 137
Results ..................................................................................................... 138
   Fillet yields and Proximate Composition ............................................ 138
   Texture and Color ............................................................................ 138
   Minerals and Amino Acids ................................................................. 139
   Sensorial Analyses ........................................................................... 139
Discussion .............................................................................................. 140

Acknowledgements .............................................................................. 123
References ............................................................................................ 124
References.................................................................................................................144

APPENDICES.............................................................................................................155

Appendix A: Human Subjects Forms for Sensory Evaluation.................................155
Appendix B: Sensory Test Scorecard (Triangle Test)................................................159
Appendix C: Fatty Acid Profiles............................................................................161

VITAE.........................................................................................................................177
### List of Figures

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter IV</td>
<td>Figure 1</td>
<td>TBARS of yellow perch fillets (-10º C) measured every two weeks during 12 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page 74</td>
</tr>
<tr>
<td>Chapter VIII</td>
<td>Figure 1</td>
<td>Proximate composition of market-sized wild (upper), farmed (middle) and genetically modified (lower) coho salmon fillets (n = 5). Fillets were divided into front, Scottish and tail cuts, each of which was further divided into dorsal and ventral halves. All data are presented as means±SD. abc superscripts indicate differences (p ≤ 0.05) between cuts in the each fish group, whereas xy signifies differences across groups.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page 153</td>
</tr>
<tr>
<td></td>
<td>Figure 2</td>
<td>Firmness (hardness) of market-sized wild (upper), farmed (middle) and genetically modified (lower) coho salmon fillets (n = 5). Fillets were divided into front, Scottish and tail cuts, each of which was further divided into dorsal and ventral halves. Firmness was measured as break force/g and maximum force/g. All data are presented as means±SD. abc superscripts indicate differences (p &lt; 0.05) between cuts in the each fish group, whereas xy signifies differences across groups.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page 154</td>
</tr>
</tbody>
</table>
# List of Tables

| Chapter III | Table 1. Moisture, fat and protein percentages of wild and farmed freeze-dried yellow perch | 47 |
| Table 2. Amino acid content of wild and farmed yellow perch fillets | 48 |
| Table 3. Mineral concentration in wild and farmed yellow perch fillets | 49 |
| Table 4. Color of minced and whole yellow perch fillets | 50 |
| Table 5. Important fatty acids concentration of wild and farmed yellow perch fillets | 51 |

| Chapter IV | Table 1. Ingredients and composition of the three experimental diets fed to yellow perch | 68 |
| Table 2. Weight gain, feed conversion efficiency and yield % in yellow perch fed diets varying protein concentration: 38 %, 45%, and 55% | 69 |
| Table 3. Water quality indexes of yellow perch fed diets varying protein concentration: 38 %, 45%, and 55% | 70 |
| Table 4. Proximate composition of yellow perch fed three diets varying protein concentration: 38 %, 45%, and 55% | 71 |
| Table 5. Color of minced yellow perch fillets fed diets varying protein concentration: 38 %, 45%, and 55% | 72 |
| Table 6. Selected fatty acid concentrations of yellow perch fed three diets varying protein concentration: 38 %, 45%, and 55% | 73 |

| Chapter V | Table 1. Ingredients and composition of the 6 experimental diets fed to southern flounder for 12 weeks. | 91 |
| Table 2. Weight gain, feed efficiency and protein efficiency ratio (means ± standard error) of southern flounder fed diets containing different dietary protein levels for 12 weeks. | 92 |
Table 3. Visceral somatic index (VSI\textsuperscript{1}), hepatosomatic index (HSI\textsuperscript{2}), relative gut length (RGL\textsuperscript{3}), lipid content of livers\textsuperscript{4} (means ± standard error) of southern flounder fed diets containing different dietary protein levels for 12 weeks.

Table 4. Blood parameters (means ± standard error) of southern flounder fed diets containing different dietary protein levels for 12 weeks.

Table 5. Whole body lipid and protein (means ± standard error) of southern flounder fed diets containing different dietary protein levels for 12 weeks.

Table 6. Protein and lipid content of inner and fin-ray muscle (means ± standard error) of southern flounder fed diets containing different dietary protein levels for 12 weeks.

Chapter VI

Table 1. A comparison of the proximate composition of farmed and wild southern flounder.

Table 2. Comparison of color of farmed and wild southern flounder fillets using a Minolta CR-200.

Table 3. A comparison of fillet mineral content between farmed and wild southern flounder.

Table 4. Concentrations of selected fatty acids in fillets of farmed and wild southern flounder.

Chapter VII

Table 1. Composition of crab meal-supplemented diet and proximate analysis of crab meal-supplemented and commercial diet.

Table 2. Proximate composition of flounder fillets fed a commercial or a crab meal-supplemented diet.

Table 3. Color of commercial, crab meal-supplemented diets and flounder fed a commercial or the crab meal-supplemented diet.

Table 4. Fatty acid composition of southern flounder fed a commercial or a crab meal-supplemented diet.
Chapter VIII

Table 1. Weight (head-on, gilled and gutted animals) and frame yields (%) of wild, farmed, and genetically modified coho salmon (n = 5)

Table 2. Color (L*, b*, a* values) of each section measured as break force and maximum force in wild, farmed and modified coho salmon fillets divided in six body zones: 1= Front dorsal; 2= front ventral; 3= Scottish dorsal; 4= Scottish ventral; 5= tail dorsal; 6= tail ventral (n=5).
Data are presented as means ± SD

Table 3. Muscle micro- (µg/100g edible muscle) and macromineral (mg/100g edible muscle) content of wild, farmed and modified coho salmon (n = 5). Data are presented as means ± SD Superscripts signify differences (p < 0.05) between groups. Bdl = below detection limits (actual detection limit)

Table 4. Essential and non-essential amino acid profiles (g/100g freeze dried muscle) of wild, farmed, and modified coho salmon. Data are presented as Means ± SD (n = 5) with different superscripts in the same row signifying significant difference (p ≤ 0.05) between groups.

Appendix C

Table C-1. Fatty acid profile (% total fatty acids) of wild and farmed yellow perch fillets (n=3; mean ± standard deviation)

Table C-2. Selected fatty acid concentrations (% of total fatty acids) of feeds varying protein concentration (38 % (YP1), 45% (YP2), 55% (YP3))

Table C-3. Fatty acid profile of yellow perch fed three diets varying protein concentration: 38% (YP1), 45% (YP2), 55% (YP3) (means ± standard deviation)

Table C-4. Fatty acid profile (% of total fatty acids) of wild and farmed southern flounder fillets (mean ± standard deviation; n = 3)

Table C-5. Fatty acid profile (% of total fatty acids) of southern flounder fed a commercial diet or a crab-meal supplemented diet (mean ± standard deviation; n = 3)

Table C-6. Complete fatty acid profile (% of total fatty acids) of wild salmon body zones (1=front dorsal; 2= front ventral; 3= Scottish dorsal; 4= Scottish ventral; 5= tail dorsal; 6= tail ventral) (n=5; mean ± standard deviation)
Table C-7. Fatty acid profile (% of total fatty acids) of farmed salmon body zones
(1=front dorsal; 2= front ventral; 3= Scottish dorsal; 4= Scottish ventral;
5= tail dorsal; 6= tail ventral) (n=5; mean ± standard deviation)

Table C-8. Fatty acid profile (% of total fatty acids) of GMO salmon body zones
(1=front dorsal; 2= front ventral; 3= Scottish dorsal; 4= Scottish ventral;
5= tail dorsal; 6= tail ventral) (n=5; mean ± standard deviation).