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DOES FISH DIET AFFECT CONSUMER DECISIONS? A NUTITIONAL AND SENSORY STUDY OF FARM-RAISED TROUT. Sarah Booth

A thesis submitted to the University Honors Program in
partial fulfillment of the requirements for the
Honors Certificate with Thesis

Approved by
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Southern Illinois University, Carbondale
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DOES FISH DIET AFFECT CONSUMER DECISIONS? A NUTRITIONAL AND SENSORY STUDY OF FARM-RAISED TROUT

Statement of Project Objectives

The focus of this study is twofold: 1) compare the nutritional value of farm-raised rainbow trout obtained from commercial sources, fed different diet regimens with that of wild-caught rainbow trout, and 2) conduct a sensory analysis test on both farm-raised and wild rainbow trout products with a consumer panel understanding their preferences and attitudes to fish consumption.

The fish samples compared for the sensory study came from the following sources: Evaqua Farms in Idaho which used a standard fishmeal-based formulation in their trout production, and McFarland Springs Trout Farm in California which used a 100% plant-protein based feed. A third group of fish was wild-caught rainbow trout procured from the North Fork Stanislaus River in California and was added for the nutritional value portion of the study only.

Dr. Karolina Kwasek, my faculty mentor for this project, analyzed proximate composition, fatty acids, and free amino acid content of the fish to generate a nutritional composition profile for all three trout groups. We specifically looked at polyunsaturated fatty acid composition because of the belief that is one of the main drivers for the consumption of fish over other forms of protein. All data collected is presented in the Data and Results section of this paper.

The sensory analysis test was performed to determine consumer preferences and attitudes comparing farm raised with wild-caught fish. In this part of the study, boneless fillet samples of the fish were similarly prepared and taste tested by an untrained consumer panel. A questionnaire given during the tasting asked for consumer preference on the appearance, texture, aroma, and flavor of the fish. This information was used to determine if consumers have a preference of fish raised on different diets. I worked with Dr. Sylvia Smith to design a survey questionnaire to determine consumer preference and attitudes to farm-raised fish. All data collected is presented in the Data and Results section of this paper.

Background and Context

Overexploitation of marine fishery resources has led to the advancement of the aquaculture industry (FAO, 2006). It has been long understood that most aquaculture diets incorporate some form of fishmeal or fish oil in their diet regimen to fulfill the dietary needs of the fish being raised. This is largely due to the fact dietary lipids affect the fatty acid composition of fish (Cahu C. et al, 2004). When aquaculture is reliant on fishmeal and fish oil for the necessary dietary lipids, low-value or trash fish and bycatch is often used as the source. The sustainability of this practice is in doubt and there are important social, economic, and ecological considerations in this system where the aquaculture industry is dependent on the marine fishing industry (FAO, 2006). In this

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study we are examining the nutritional value of fish raised different diets and also assessing if sustainability influences purchasing behavior.

According to data compiled by Tacon and Metian, in 2007 the United States produced 20,000 tons of trout including *Oncorhynchus mykiss*, *Salvelinus fontinalis*, and *Salmo trutta*. *Oncorhynchus mykiss* is the species examined in our study. Of the 20,000 tons of fish produced in the United States there was a feed conversion ratio (FCR) of 1.3:1 with a fish meal percentage of 20-30% (24% was the mean amongst producers) and a fish oil percentage of 4%-10% (8% mean). Recent FAO statistics show that since that time global production of rainbow trout has increased from 666,444 tons to 814,090 tons in 2016. While FCR has improved to be close to 1:1 the increased production rates still stress the need for further reducing the amount of fishmeal and fish oil in aquaculture diets (FAO, 2017).

That is in part why this study has importance to the aquaculture industry. A producer, McFarland Springs, advertises their product as being raised on a 100% vegetarian red-algae based feed formulation that uses no fish byproduct whatsoever. While many of these alternative diets are still in the early stages of development and production, case studies have indicated the fillets are comparable in terms of flavor and nutrition (Rust M, et. al 2011). We wanted to see if a difference between this diet regimen and a conventional conservative fishmeal-based regimen was noticeable to a consumer and if the nutritional composition of the filet was affected by the alternative diet. Doing the study also gave us an opportunity to examine purchasing attitudes and see how addressing sustainability issues may affect purchasing behaviors.

Methods and Procedures

The nutritional analysis was completed in the Aquaculture lab at SIUC. 3 fish muscle samples from each group were analyzed. A total of 9 samples were processed, with 3 replicates for each group of fish being tested. Frozen fish muscle samples were ground up and analyzed for ash combustion in a muffle furnace. Crude protein was determined using a nitrogen analyzer and crude lipids were also extracted and measured. Free amino acids in fish muscle tissue, which are the indicators of dietary amino acid availability were analyzed using High Performance Liquid Chromatography. All data was analyzed using analysis of variance (ANOVA) to detect any differences in nutrient levels in fish muscle from different groups.

For the sensory analysis study, a preference ranking test was used to compare the two farm-raised trout samples. The three samples were given to an untrained consumer panel for sensory analysis and tasting and asked to select their preference. The consumer panel was open to the public but was largely comprised of college age young adults. All panel members were asked to complete a survey in regards to their fish consumption behaviors and attitudes that may affect their purchasing behaviors.

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The sensory test took place on the SIUC campus in the Food and Nutrition kitchens in the Quigley building. There are two kitchens in Quigley; one kitchen was used for preparation of the fish, the other for tasting. All fish were prepared using the same method (baked to an internal temperature of 145 °F) and served small two-ounce portions on randomly numbered plates. There was no oil or seasoning used on the fish during preparation. All fish filets were skinned and, if needed, deboned before baking. The McFarland Springs fish needed to be deboned manually whereas the Evaqua Farms fish were mechanically deboned at harvest.

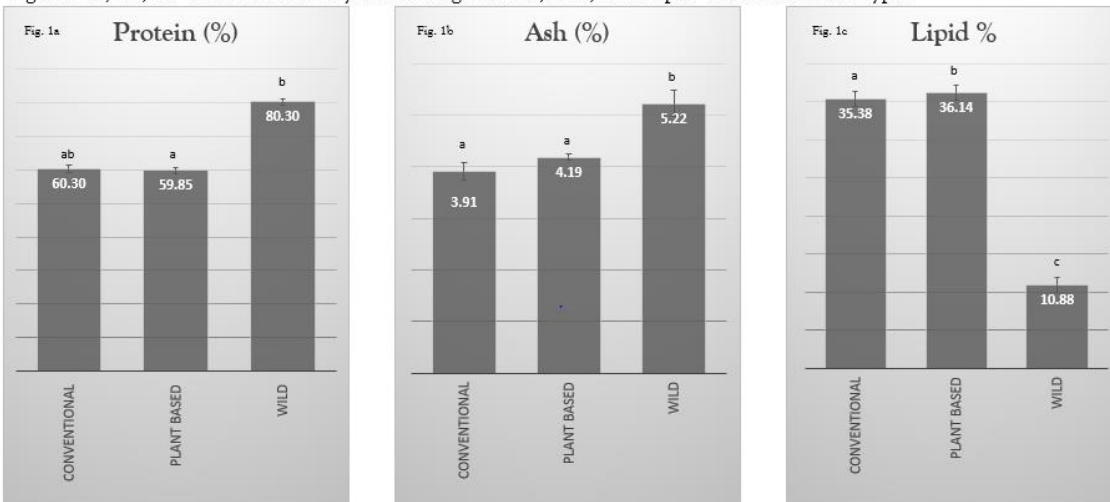
All fish arrived to the campus fresh and was frozen until sampling was needed for each study. Because the nutritional value and sensory studies were taking place at different times, this was the best way to ensure identical treatment of each group, while keeping costs within the budget allocated by the REACH grant. The fish all varied in age with the McFarland Springs fish reportedly being the oldest at 2-4 years old at harvest. The Evaqua Farms fish were between 1-2 years old at time of harvest. The wild caught fish all appeared to be juveniles under a year old.

Data and Results

In all tables and graphs “Conventional” will refer to the fish raised on a conservative fishmeal or fish oil-based aquaculture diet. The label “Plant Based” will refer to the 100% vegetarian red-algae based diet, while “Wild” refers to the wild-caught fish that had the wild-type diet.

Figures 1a, 1b, and 1c show the protein, ash and lipid content for the fish in our study. The protein and ash content of the two farm-raised fish were statistically similar whereas the wild fish differed. While at first glance the lipid content percentages seemed similar in the farm-raised fish; a statistical difference in all three diets was observed.

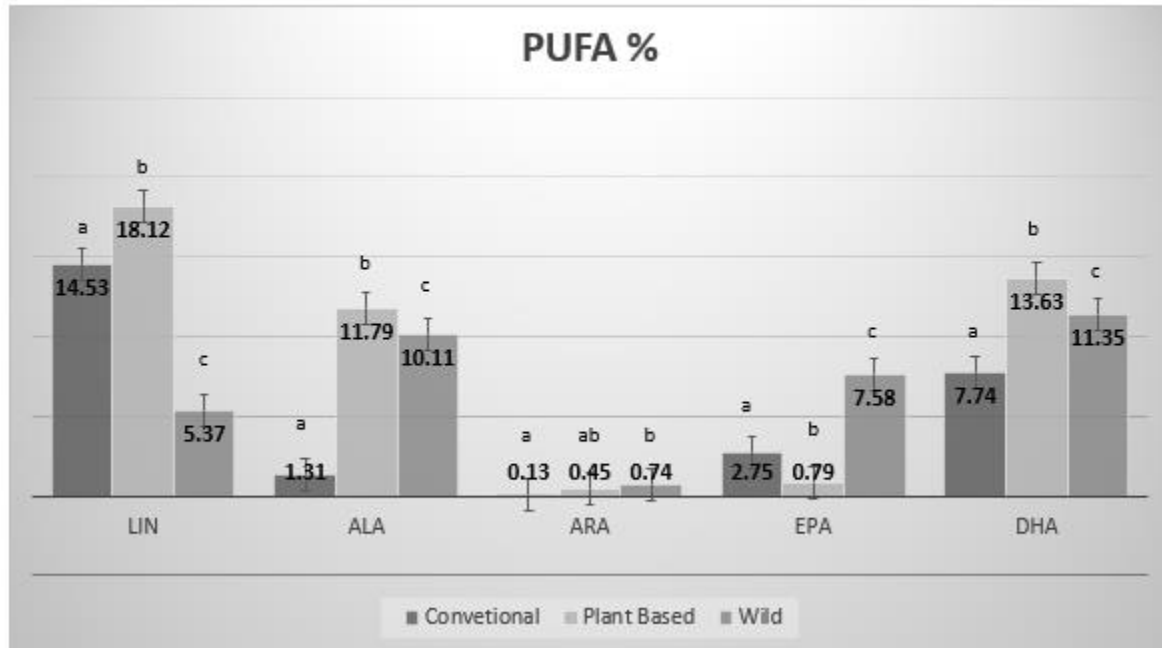
Figures 1a, 1b, 1c - Proximate Analysis showing Protein, Ash, and Lipid % based on diet type.



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The polyunsaturated fatty acid (PUFA) composition is described in Figure 2. The fatty acids analyzed in particular are linoleic acid (LIN), alpha-linoleic acid (ALA), arachidonic acid (ARA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Statistical differences were observed for all three diets in regard to percentage of LIN, ALA, EPA, and DHA present in the filet. In regard to ARA, the plant-based diet was similar to both the conventional and wild diets; however, there was a dissimilarity between the conventional and wild-type diets.

Figure 2: Polyunsaturated Fatty Acid Composition according to diet type



The PUFA ratio of N6:N3 is calculated in Figure 3. The N6 omega fatty acids are linoleic and arachidonic fatty acids. The N3 omega fatty acids are alpha-linoleic, eicosapentaenoic, and docosahexaenoic acids.

Figure 3: Omega Fatty Acid N6:N3 ratio

Diet Type	N6	N3	N6:N3
Conventional	14.66%	11.80%	1.24:1
Plant Based	18.57%	26.21%	.71:1
Wild Diet	6.11%	29.03%	.21:1

Figure 4 and Figure 5 show the age and gender distribution of the sensory study participants. Over half the study population was in the 18-24 age bracket and 73.7% of the study participants were under the age of 34. There was a slightly larger representation of males (31) to females (26) that took part in the sensory study.

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Figure 4: Sensory Study Participant Age Distribution

Age	Frequency	Population Percentage
18-24	30	52.6%
25-34	12	21.1%
35-44	3	5.2%
45-54	7	12.3%
55-64	4	7.0%
65+	1	1.7%
Total Participants	57	100%

Figure 5: Sensory Study Gender Distribution

Gender	Frequency	Distribution %
Male	31	54.4%
Female	26	45.6%
Total	57	100%

Figures 7, 8, and 9 reflect consumption frequency, knowledge of fish, and attitudes that may affect purchasing behavior. According to Figure 7, most participants in the study (75.4% total) consumed fish less than twice per month. Figure 8 shows a relatively equal distribution in self-reported knowledge of fish with 16 participants reporting a Low knowledge level, 20 participants reporting a Medium knowledge level, and 21 participants reporting a high knowledge level. In Figure 9 all participants rated different labels on a scale of 1-5 in how different labels affected their attitudes toward purchasing a fish product, with 1 being least likely to purchase and 5 being most likely to purchase. The labels examined for this study were Sustainably Raised Fish (mean score 3.95), Product of the USA (mean score 3.95), and Certified Humanely Raised (mean score 4.05). The data indicates the presence of these labels positively influences purchasing behavior.

Figure 7: Sensory Study Participant Purchasing Frequency

How often participants reported eating fish		
	Frequency	Percentage
Never	1	1.8%
Once every 2-3 months	11	19.3%
Once or twice a month	31	54.4%
Once or twice a week	14	24.6%
Total	57	100%

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Figure 8: Sensory Study Participant General Knowledge Level Regarding Fish

General knowledge of fish		
	Frequency	Percentage
Low	16	28.1%
Medium	21	36.8%
High	20	35.1%
Total	57	100%

Figure 9: Sensory Study Participant Attitudes That Affect Purchasing Behavior

Attitudes that affect purchasing behavior				
	Number of Responses	Minimum Score	Maximum Score	Mean
Sustainably raised fish	57	1.00	5.00	3.95
Product of USA	57	1.00	5.00	3.95
Certified humanely raised	57	1.00	5.00	4.05

The Figures 10 and Figures 11 indicate if there was a preference for one fish over another. The Conventional diet was generally preferred with 31 (52.6%) of the study participants selecting it over the Plant-based diet which was selected by 26 (43.9%) of the study participants. Although not an option presented on the form, 2 (3.5%) participants did not select a preference for either fish. The descriptive statistics in Figure 11 show a general preference for the fish fed the Conventional diet over the fish fed the Plant-based diet. This scale was on a range from 0-9 with 9 being the highest rating possible. The biggest variance being in the Overall Appearance which has a mean score of 7.05 for Conventional and 5.83 on the Plant-based.

Figure 10: - Sensory Study Preference Based on Diet Type

Preferred Diet Type	Frequency	Percent
Conventional	31	52.6%
100% Plant Based	26	43.9%
None Selected	2	3.5%
Total	57	100%

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Figure 11: Sensory Study Overall Opinion Scores; Scores were based on a scale from 0-9

	Conventional Diet Mean Score	100% Plant-Based Mean Score
Overall Opinion	6.86	6.48
Overall Appearance	7.05	5.83
Overall Aroma	6.55	6.23
Overall Flavor	6.75	6.21
Overall Texture	7.05	6.69

Discussion

When doing the proximate analysis and the fatty acid composition for the nutritional value portion of the study, three samples were collected from varying parts of the filet. This accounts for the varied makeup of lipid composition in trout and other salmonids where a gradient of fat deposition can be found depending on the muscle sampled. Specifically, it has been observed in salmonids that a greater fat level was found in ventral part as compared to the dorsal part and posterior as compared to the anterior (Hendersen R and Tocher D, 1987). Sampling from various parts of the filet produce results more representative of the entire fish.

All fish were also harvested at roughly the same time which can also impact test results. It has been observed at least in wild caught sardines that lipid levels and PUFA concentrations varied throughout the year (Bandarra et. al, 1997). For example, general lipid levels were lowest during spawning (in March) and PUFA concentrations were highest in May (Bandarra et. al, 1997). Another study showed a variance in lipid levels for red drum depending on time of year, but no difference on ash or protein content (Jahncke M., et. al, 1988). All fish in this study were harvested in early September 2019.

Ratio of N6:N3 PUFA was examined in this study because of increasing importance not just on obtaining adequate amounts of omega N3 fatty acids in the diet but also because studies are now investigating the ratio of N6:N3 and how that affects human health and inflammatory responses (Soborg Husted K, Bouzinova E., 2016). A lipid panel of experts has recommended that ideal ratio of N6:N3 be around 2:1 (Simopoulos A, Leaf A, and Salem Jr. N, 1999) but the Western diet can often present ratios of 15-20:1 (Simopoulos A, 2009).

Between the two farm-raised diets, the overall PUFA levels were highest in the Plant-based diet and the N6:N3 ratio was lowest in that diet as well. This reflects a similar result seen in farm raised tilapia that were tested for PUFA levels on diets with corn oil, fish oil, or algal oil at various concentrations (Stoneham et. al, 2018). The tilapia from that study with the highest long chain PUFA content and the lowest N6:N3 ratio was the fish fed a concentrate of 8.77% algae meal

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(Stoneham et. al, 2018). All three fish in this study have levels much lower than the 2:1 ratio listed as ideal and would be a good addition to any diet to help offset the problems seen in the standard Western diet.

The diet fed to farmed fish affects the parameters determining the quality of the fish fillets proposed to consumers (Cahu, et al., 2004). These parameters are including attributes such as texture, appearance, smell, taste and pigmentation (Cahu, et al., 2004). In our sensory study there was a preference for the fish fed the Conventional diet but there are limitations that should be discussed in regard to that data. The farm-raised fish came from two different producers that demonstrated much different levels of proficiency when running their operations. The Conventional diet producer raised their fish to be about 1-2 years old at harvest. The Plant-based diet producer indicated their fish are 2-4 years old at harvest. Optimal harvest size in the US is more in line with the Conventional diet age whereas in Europe optimal harvest size and age is more inline with the Plant-based Diet (The Fish Site, 2020). Handling was also a concern as we noted that the Conventional diet was mechanically deboned before shipment and the Plant-based diet fish had to be manually deboned at time of preparation. It is likely this extra added stress on the fish filets at time of preparation in some part caused the discrepancy in Appearance and Texture scores for the Plant-based fish. We also know that different systems are used by each producer as one advertises using a river raceway and the other reportedly uses tanks. The results of the study while not insignificant highlight a need to it to be repeated with more standardization in place.

Conclusions

The data from this study showed a higher PUFA content in fish raised on the Plant based diet. The sensory study results indicate a preference the fish raised on the Conventional diet. While these results are not conclusive because of the known variables, this study could be repeated with more standardization. Using a single producer with controlled rearing, handling, feeding, harvest and packaging practices would likely address the concerns noted in this study regarding fish age and production variables. Given that the results were close with the known differences it is likely that gap could be closed further demonstrating the ability to further reduce fishmeal and fish oil in conventional diets or add more algae oil to remove it completely. Being able to label a fish as more sustainably raised in the USA would increase its acceptance at market.

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About the Author

Sarah Booth is currently an undergraduate student at SIU fulfilling an undergraduate degree in Animal Science with a concentration on Pre-Veterinary Medicine. After her graduation in May 2021 she is looking to enroll in a D.V.M. or PhD program with an emphasis on animal nutrition.