Fisheries and Aquaculture Journal

Brown et al., Fish Aquac J 2016, 7:1
DOI: 10.4172/2150-3508.1000163

Research Article

Open Access

# Retention of Fillet Coloration in Rainbow Trout After Dietary Astaxanthin Cessation

**Katherine R Brown[1], Michael E Barnes[1]*, Timothy M Parker[1] and Brian Fletcher[2]**

*[1]McNenny State Fish Hatchery, South Dakota Department of Game, Fish and Parks, 19619 Trout Loop, Spearfish, South Dakota-57783, USA*
*[2]Cleghorn Springs State Fish Hatchery, South Dakota Department of Game, Fish and Parks 4725 Jackson Boulevard, Rapid City, South Dakota-57702, USA*

## Abstract

This study was conducted to determine the retention time of rainbow trout (*Oncorhynchus mykiss*) fillet coloration, as indicated by hue, chroma, and entire color index (ECI) values, after the cessation of dietary astaxanthin. After 12 weeks of receiving a diet containing astaxanthin, rainbow trout [mean (SD) length 240 (26) mm, weight 194 (65) g] were either switched to a non-astaxanthin diet or continued to receive the same astaxanthin diet for 55 d. In addition, a control group was fed a non-astaxanthin diet for the entire duration of the study. Digital coloration measurements (L*, a*, and b*) were recorded on fillets and used to calculate hue, chroma, and ECI values. Hue, chroma, and ECI did not significantly change within any of the treatments over the course of the study. Hue, chroma, and ECI were also not significantly different between the fillets of those fish that either continued to receive astaxanthin-supplemented feed compared to those that were switched from an astaxanthin diet to diet free of astaxanthin. However, ECI, hue, and chroma were significantly different in fillets from the fish that had never received dietary astaxanthin compared to fillets from the other two treatments. These results indicate that catchable-sized rainbow trout stocked into recreational fishing waters with minimal natural feed should retain fillet coloration for at least 55 d after stocking, making astaxanthin supplementation in recreational hatcheries a viable tool to improve angler satisfaction.

**Keywords:** Rainbow trout; Astaxanthin; *Oncorhynchus mykiss*; Coloration

## Introduction

Consumer and angler satisfaction is of great importance for both commercial and recreational aquaculture. The work of Forsberg and Guttormsen stated that with salmon, the appearance of wild characteristics is the most important criteria of perceived quality by consumers [1]. Fillet coloration is particularly important. In rainbow trout (*Oncorhynchus mykiss*), fillets containing red pigmentation are deemed much more desirable than non-pigmented, white fillets [2]. A 2009 study also found a positive relationship between color and consumer demand in snapper (*Pagrus auratus*) [3]. In recreational fisheries, Simpson reported that anglers overwhelmingly preferred more brightly colored rainbow trout, as well as more red-colored trout fillets [4].

The red fillet color preferred by both consumers and recreational angler's results primarily from the consumption of astaxanthin, a carotenoid pigment that fish cannot synthesize de novo [5]. Astaxanthin occurs in many prey items consumed by wild fish, while in cultured fish this pigment must be provided in the artificial diets [5]. Including the synthetic or natural forms of astaxanthin in formulated feeds increases production costs, but this is typically more than compensated by increases in pricing power [1], or in the case of natural resource agencies, by increases in angler satisfaction [4]. However, anglers in the Simpson survey were not told that such coloration in hatchery fish would require the addition of supplemental astaxanthin [4].

The time and amount of astaxanthin supplementation required to produce red-colored fillets in salmonids is well documented [1,6-8]. However, unlike trout produced for direct human consumption by commercial aquaculture which are slaughtered at peak coloration, trout produced for stocking into water bodies by recreational hatcheries may be harvested months after stocking [9].

A 1998 study reported few differences in the color of frozen fillets from Atlantic salmon Salmo salar starved for up to 86 days after being fed a diet containing astaxanthin [10]. Except for the very short duration experiment of López-Luna, we are not aware of any studies that have examined long-term coloration depletion rates and subsequent changes in fillet coloration following the cessation of feeding dietary astaxanthin in rainbow trout [11]. This information is needed by resource agencies and other organizations to determine the effectiveness and utility of stocking of catchable-sized rainbow trout with red-colored fillets due to supplemental astaxanthin. Thus, the objective of this study was to examine the long-term effects on rainbow trout fillet coloration after the removal of supplemental dietary astaxanthin.

## Methods

This study was conducted at Cleghorn Springs State Fish Hatchery, Rapid City, South Dakota, USA, using degassed and aerated spring water (11°C, total hardness as $CaCO_3$, 36 mg $L^{-1}$; alkalinity as $CaCO_3$, 210 mg $L^{-1}$; $p^H$-7.6; total dissolved solids, 390 mg $L^{-1}$). Four circular production tanks (6.1 m diameter, 0.9 m operating depth), each containing approximately 5,500 Erwin-Arlee strain rainbow trout [mean (SD) length 240 (26) mm, weight 194 (65) g] were initially used in this experiment. Beginning on June 4, 2008, two of the tanks were fed a 4.5 mm classic trout diet (Skretting, Tooele, Utah, USA), while

***Corresponding author:** Michael E Barnes, McNenny State Fish Hatchery, South Dakota Department of Game, Fish and Parks, 19619 Trout Loop, Spearfish, South Dakota-57783, USA, Tel: 605-642-1262; Fax: 605-642-6921; E-mail: mike.barnes@state.sd.us

**Received** January 26, 2016; **Accepted** March 21, 2016; **Published** March 28, 2016

**Citation:** Brown KR, Barnes ME, Parker TM, Fletcher B (2016) Retention of Fillet Coloration in Rainbow Trout After Dietary Astaxanthin Cessation. Fish Aquac J 7: 163. doi:10.4172/2150-3508.1000163

**Copyright:** © 2016 Brown KR, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Citation:** Brown KR, Barnes ME, Parker TM, Fletcher B (2016) Retention of Fillet Coloration in Rainbow Trout After Dietary Astaxanthin Cessation. Fish Aquac J 7: 163. doi:10.4172/2150-3508.1000163



the other two tanks were fed the same diet with the inclusion of 40 mg/L synthetic astaxanthin. Feeding rates were based on a projected growth rate of 0.065 cm/day and an anticipated feed conversion ratio of 1.1. Because the fish were part of normal hatchery production, small numbers of fish were periodically removed from each tank for stocking into recreational fishing waters. As the number of fish in each tank changed, feeding amounts were adjusted correspondingly.

Weekly measurements of fillet color were obtained from fish euthanized by a lethal dose of 250 mg/L MS-222 using a HunterLab MiniScan XE Plus Colorimeter (HunterLab, Reston, Virginia, USA). Measurements occurred mid-fillet, below the dorsal fin and above the lateral line. Color was measured from whole fillets, rather than ground tissue, because this coloration would be most evident to the recreational angler. The colorimeter measured color along the CIELAB color scale (CIE 1976), which includes L*, a*, and b* values. The a* score indicates red-green chromaticness and b* indicates yellow-blue chromaticness [7]. L* indicates white-to-black values [12]. At 12 weeks, after which a* values were no longer increasing in the tanks receiving supplemental astaxanthin, one-half of these fish were switched to a non-astaxanthin diet and moved into two additional tanks. Fillet color data was then collected at approximately 14 day intervals for the next 55 days. The focus of this study was solely on changes in coloration, not growth or any other rearing variable. Thus, only coloration data was collected.

The L*, a*, and b* values were used to calculate Hue, Chroma, and the Total Color Index using the following formulas:

$$Hue = \arctan\left(b*/a*\right)$$

$$Chroma = \left[\left(a*2 + b*2\right)1/2\right]$$

$$Entire\ Color\ Index\left(ECI_i\right) = C_i * \cos\left(H_i - H_{mean}\right),$$

Where $H_{mean} = mean\ hue$ and $C_i$, $H_i$ =the chroma and hue values for each measurement [13].

Statistical analysis was done using Minitab 16 software (Minitab Inc., State College, Pennsylvania, USA). Color depletion data was analyzed using multiple regression models. Models were done using the overall means of the treatments at each measurement to determine significance in changes of color variables. Statistical significance was predetermined at $P<0.05$.

## Results

Hue, chroma, and ECI did not significantly change in any of the treatments over the course of the study (Figures 1-3). Hue, chroma, and ECI were also not significantly different between the fillets of those fish that either continued to receive astaxanthin-supplemented feed (Color) compared to those that were switched from an astaxanthin diet to diet free of astaxanthin (Depletion). However, ECI, hue, and chroma were significantly different in fillets from the fish that had never received dietary astaxanthin (No Color), compared to fillets from both Color and Depletion treatment fish.

Best fitted models for each color variable are as follows:

a) **Hue:** No Color=-27.75-0.00073 (Date); Color and Depletion=-27.9-0.00073 (Date) $R^2$=60.1, d.f=2,10.

b) **Chroma:** No Color=261.15-0.0062 (Date); Color and Depletion=268-0.0062 (Date) $R^2$=91.8, d.f=2,10.

c) **ECI:** No Color=258.18-0.0061(Date); Color and Depletion=263-0.0061 (Date) $R^2$=91.8, d.f=2,10.

## Discussion

These results indicate that, at least for the 55 d duration of the study, there was no loss in fillet coloration after the cessation of feeding dietary astaxanthin. This timing is important in recreational fisheries sustained by the stocking of catchable-sized rainbow trout into waters with minimal natural feed. In a study conducted by Barnes, most of the rainbow trout stocked into two public fishing lakes were caught within the first few weeks after stocking, and nearly all of the fish were harvested within the first 55 days [9]. Thus, natural resource agencies can feed supplemental astaxanthin to catchable rainbow trout without concern that the internal and external benefits of pigmentation will disappear before the fish are caught, thereby meeting angler preferences for more colorful fish and fillets [4].

The results from this study also have application to commercial trout hatcheries, where fillet coloration influences customer perceptions of quality, customer demand, and pricing power [1-3,13,14]. Rather than incur the expense of feeding supplemental astaxanthin until the trout

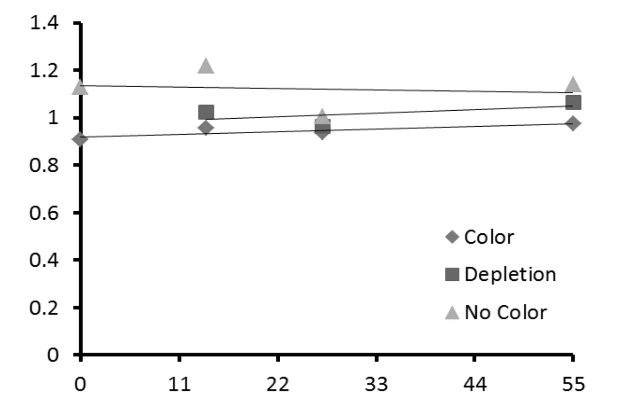


**Figure 1:** Mean hue values from fillets of rainbow trout subjected to one of three treatments:
a) Fed feed void of supplemental astaxanthin (no color),
b) Fed non-astaxanthin supplemented feed (color), or
c) Fed feed supplemented with astaxanthin for 12 weeks prior to the start of the experiment and then switched to non-astaxanthin feed (depletion).

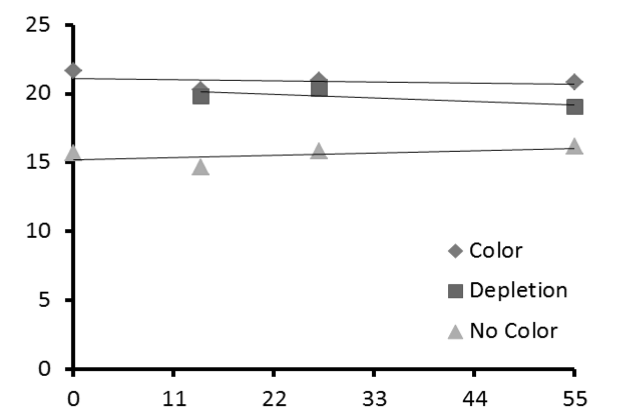


**Figure 2:** Mean chroma values from fillets of rainbow trout subjected to one of three treatments:
a) Fed feed void of supplemental astaxanthin (no color),
b) Fed non-astaxanthin supplemented feed (color), or
c) Fed feed supplemented with astaxanthin for 12 weeks prior to the start of the experiment and then switched to non-astaxanthin feed (depletion).

**Citation:** Brown KR, Barnes ME, Parker TM, Fletcher B (2016) Retention of Fillet Coloration in Rainbow Trout After Dietary Astaxanthin Cessation. Fish Aquac J 7: 163. doi:10.4172/2150-3508.1000163



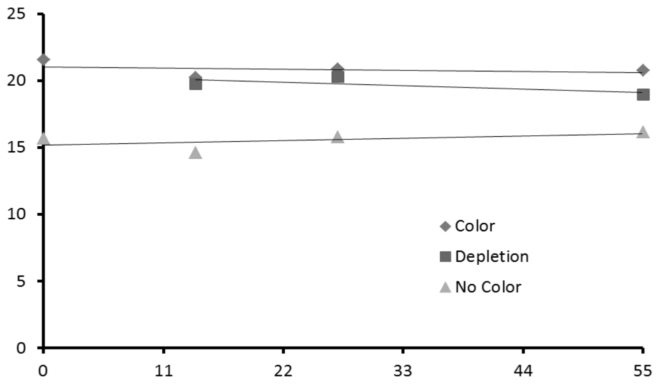


**Figure 3:** Mean Entire Color Index values from fillets of rainbow trout subjected to one of three treatments:
a) Fed feed void of supplemental astaxanthin (no color),
b) Fed non-astaxanthin supplemented feed (color), or
c) Fed feed supplemented with astaxanthin for 12 weeks prior to the start of the experiment and then switched to non-astaxanthin feed (depletion).

are ready for market, producers could discontinue feeding astaxanthin at 55 d pre-harvest and still maintain the fillet color so desired by consumers. With astaxanthin accounting for as much as 10%-15% of total feed costs, the cessation of feeding astaxanthin for nearly two months would produce considerable cost-savings [3].

López-Luna noted no difference in fillet L*, a*, and b* values of rainbow trout previously fed astaxanthin after three days of starvation at 11.5°C (34.1 degree-days, whereby one degree-day equals 24 hours at 1°C) [11]. Our study extends this timeframe out to 605 degree-days (55 days at 11°C). In frozen fillets from Atlantic salmon starved for up to 86 days after being fed a diet containing astaxanthin, no differences in hue or red (a*) values were observed by Einen and Thomassen [10]. The lack of decrease in fillet coloration over 55 days likely reflects the ability of rainbow trout muscle to store relatively large amounts of astanxanthin [15].

The color values are well within the range reported for rainbow trout in other studies involving astaxanthin [6,11,12,16,17]. Although the results from this study are likely applicable to other strains of rainbow trout, the influence of other dietary factors on astaxanthin absorption and ultimately fillet coloration could potentially influence the results if different diets are used [18].

This study only examined the loss of coloration in trout fillets. It does not address any potential issues that recreational anglers or consumers may have about the use of synthetic astaxanthin in hatchery diets [19,20].

## Acknowledgement

We thank Greg Simpson, Will Sayler, John Carriero, and Joseph Barnes for their assistance with this study.

## References

1. Forsberg O, Guttormsen A (2006) Modelling optimal dietary pigmentation strategies in farmed Atlantic salmon: Application of mixed-integer non-linear mathematical programming techniques. Aquaculture 261: 118-124.
2. Folkstead A, Wold JP, Rorvik K (2008) Rapid and non-invasive measurements of fat and pigment concentrations in live and slaughtered Atlantic salmon (Salmo salar L.). Aquaculture 280: 129-135.
3. Doolan BJ, Booth MA, Allan GL (2009) Effects of dietary astaxanthin concentration and feeding period on the skin pigmentation of Australian snapper Pagrus auratus. Aquaculture Res 40: 60-68.
4. Simpson G (2009) Angler Use and Harvest Survey of Center Lake, South Dakota. South Dakota Department of Game, Fish and Parks Report, Pierre, South Dakota pp: 4-10.
5. Choubert G, Blanc JM (1997) Colour measurements, using the CIELCH colour space, of muscle of rainbow trout, Oncorhynchus mykiss (Walbaum), fed astaxanthin: effects of family, ploidy, sex, and location of reading. Aquaculture Res 28: 15-22.
6. Nickel DC, Bromage NR (1998) The effect of timing and duration of feeding astaxanthin on the development and variation of fillet colour and efficiency of pigmentation in rainbow trout (Oncorhynchus mykiss). Aquaculture 169: 233-246.
7. Smith B, Hardy RW, Torrissen OJ (1992) Synthetic astaxanthin deposition in pan-sized coho salmon (Oncorhynchus kisutch). Aquaculture 104: 105-119.
8. Storebakken T, Choubert G (1991) Flesh pigmentation of rainbow trout fed astaxanthin or canthaxanthin at different feeding rates in freshwater and saltwater. Aquaculture 95: 289-295.
9. Barnes ME, Simpson G, Durben DJ (2009) Post stocking Harvest of Catchable-Sized Rainbow Trout Enhanced by Dietary Supplementation with a Fully Fermented Commercial Yeast Culture during Hatchery Rearing. NA J Fish Manage 29: 1287-1295.
10. Einen O, Thomasson MS (1998) Starvation prior to slaughter in Atlantic salmon (Salmo salar) II. White muscle composition and evaluation of freshness, texture and colour characteristics in raw and cooked fillets. Aquaculture 169: 37-53.
11. López-luna J, Torrent F, Villarroel M (2014) Fasting up to 34°C days in rainbow trout, Oncorhynchus mykiss, has little effect on flesh quality. Aquaculture 420: 63-70.
12. Choubert G (2010) Response of rainbow trout (Oncorhynchus mykiss) to varying dietary astaxanthin/canthaxanthin ratio: colour and carotenoid retention of the muscle. Aquaculture Nutrition 16: 528-535.
13. Pavlidis M, Papandroulakis N, Divanach P (2006) A method for the comparison of chromaticity parameters in fish skin: Preliminary results for coloration pattern of red skin Sparidae. Aquaculture 258: 211-219.
14. Doolan BJ, Booth MA, Jones PL, Allan GL (2007) Effect of cage colour and light environment on the skin colour of Australian snapper Pagrus auratus (Bloch & Schneider, 1801). Aquaculture Res 38: 1395-1403.
15. Choubert G (1985) Effects of starvation and feeding on canthaxanthin depletion in the muscle of rainbow trout (Salmo gairdneri Rich). Aquaculture 46: 293-298.
16. Choubert G, Mendes-Pinto MM, Morais R (2006) Pigmenting efficacy of astaxanthin fed to rainbow trout Oncorhynchus mykiss: Effect of dietary astaxanthin and lipid sources. Aquaculture 257: 429-436.
17. Choubert G, Cravedi JP, Laurentie M (2009) Effect of alternative distribution of astaxanthin on rainbow trout (Oncorhychus mykiss) muscle pigmentation. Aquaculture 286: 100-104.
18. Chimsung N, Tantikitti C, Milley JE, Trichet VV, Lall SP (2014) Effects of various dietary factors on astaxanthin absorption in Atlantic salmon (Salmo salar). Aquaculture Res 45: 1611-1620.
19. Olesen I, Alfnes F, Røra MB, Kolstad K (2010) Eliciting consumer's willingness to pay for organic and welfare-labelled salmon in a non-hypothetical choice experiment. Livestock Sci 127: 218-226.
20. Steine G, Alfnes F, Rør MB (2005) The effect of colour on consumer WTP for farmed salmon. Marine Resource Econ 20: 211-219.