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# Effect of moist or dry heat cooking procedures on carotenoid retention and colour of fillets of rainbow trout (*Oncorhynchus mykiss*) fed astaxanthin or canthaxanthin

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ABSTRACT

Rainbow trout were pigmented with diets containing astaxanthin or canthaxanthin for 100 days, and then they were moist or dry heat-cooked. Fish fillet weight, fillet colour, and fillet biochemical contents (moisture, canthaxanthin and astaxanthin contents, and total lipid content) were analyzed. There was no significant effect of using astaxanthin or canthaxanthin on moisture, lipid or carotenoid contents of fish fillet. Giving astaxanthin or canthaxanthin to fish resulted in different hues; astaxanthin-fed fish yielded fillets that were visually more red than those of canthaxanthin-fed fish. The dry heat-cooking procedure showed the highest impact on the fillet colour. Carotenoid retention was affected by carotenoid source and cooking procedure. Canthaxanthin appeared more stable after heat processing than did astaxanthin.


## 1. Introduction

The pink to red colour of rainbow trout muscle is an important quality attribute for fish farmers and for consumers. This colour is caused by accumulation of carotenoids from the food, since fish are not able to synthesize them *de novo* (Goodwin, 1951). Since astaxanthin (β,β-carotene-3,3′-dihydroxy-4,4′-dione) is the major pigment of wild trout (Schiedt, Vecchi, & Glinz, 1986), both astaxanthin and canthaxanthin (β,β-carotene-4,4′-dione) are added to the feed of intensively reared rainbow trout.

The consumption of raw fish is rare in Western society and information about carotenoid contents of raw fish may be of limited value for a conclusion about their food quality. Cooking methods can have a detrimental effect on the nutrient composition (Tokur, 2007) and sensory quality (Freeman, 1999) of fish. Fish are exposed to different conditions during the cooking process which may, in turn, result in changes in their carotenoid content and may lead to colour modifications (Bhattacharya, Choudhury, & Studebaker, 1994). Carotenoids are known to deteriorate rapidly on exposure to heat (structural changes) or to light (oxidation) which results in fading, darkening or change in hue (Bauernfeind, Brubacher, Kläui, & Marusich, 1971). Traditional ovens, more than microwave ovens, are widely used at home to cook fish. Steaming, a moist heat-cooking procedure, is the most representative industrial cooking system, and it results in various food quality traits (Barbanti & Pasquini, 2005). However, this combined cooking technique is quite complex because it leads to unpredictable results due to effects of steam on meat products (Barbanti & Pasquini, 2005). While investigations into carotenoid utilization by fish are numerous (Bjerkeng, 2000), little is known about the effect of processing on the stability of carotenoids. Few controlled studies have compared the carotenoid retention and the colour of salmonid fillets that contain carotenoids such as astaxanthin and canthaxanthin (Skrede & Storebakken, 1986).

This investigation studies the effect of cooking procedures (dry and moist heat-cooking) on fillets from fish fed diets containing astaxanthin or canthaxanthin, and analyses the carotenoid retention and colour of fish fillets.

## 2. Material and methods

### 2.1. Fish and facilities

Rainbow trout (*Oncorhynchus mykiss*) from the same parental stock were obtained from the Inra experimental fish farm (Donzacq, Landes department, France). Fish were fed on a diet (the composition of which is given in Table 1) containing 100 mg of astaxanthin (Carophyll pink™, DSM, Paris, France) or 80 mg of canthaxanthin (Carophyll red™, DSM, Paris, France)/kg of diet as

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**Table 1**
Formula, ingredients and chemical composition of the basal diet.

| Diet label | | | Basal (%) |
|---|---|---|---|
| Feed ingredients (g kg$^{-1}$) | | | |
| Fish meal[a] | | | 56 |
| Gelatinised corn starch[b] | | | 13.5 |
| Crude corn starch[c] | | | 18 |
| Scandinavian fish oil[d] | | | 9 |
| Vitamin mix[e] | | | 1.5 |
| Mineral mix[f] | | | 1 |
| Sodium alginate[g] | | | 1 |
| Astaxanthin (mg kg$^{-1}$) (diet 1)[h] | | | 100 |
| Canthaxanthin (mg kg$^{-1}$) (diet 2)[i] | | | 80 |
| Diet chemical composition[j] | 1 | 2 | |
| Dry matter DM (%) | 89.7 | 91.2 | |
| Total lipids (% DM) | 14.4 | 14.9 | |
| Astaxanthin (mg kg$^{-1}$) | 98.9 | | |
| Canthaxanthin (mg kg$^{-1}$) | | 80.8 | |

[a] Norwegian herring meal, Norse LT94, Sopropêche, 62204 – Boulogne-sur-mer, France.
[b] Amidex, Ogilvie Aquitaine, 33000 – Bordeaux, France.
[c] Descal, 40360 – Pomarez, France.
[d] Feedoil, La Lorientaise, Sopropêche, 56100 – Lorient, France.
[e] INRA 762. Vitamin mix contained the following mixed with cellulose (g kg$^{-1}$ mix): vitamin A (500,000 IU g$^{-1}$), 1.5; vitamin D3 (100,000 IU g$^{-1}$), 1.5; vitamin E (500 IU g$^{-1}$), 6; vitamin K, 0.25; thiamin, 0.75; riboflavin, 1.5; pyridoxine, 0.75; nicotinic acid, 8.75; vitamin C, 25; folic acid, 0.25; vitamin B12 (1000 mg kg$^{-1}$), 2.5; inositol, 50; biotin (2 mg kg$^{-1}$), 6.25; calcium pantothenate, 2.5; choline (50 mg kg$^{-1}$), 200.
[f] INRA 763. Mineral mix contained the following ingredients (g kg$^{-1}$ mix): calcium carbonate, 215; magnesium hydroxide, 124; KCl, 90; ferric citrate, 20; KI, 0.4; NaCl, 40; calcium hydrogen phosphate ($CaHPO_4$), 500; copper sulfate, 3; zinc sulfate, 4; cobalt sulfate, 0.2; manganese sulfate, 3.
[g] Alginate GF 150. Louis François Exploitation, 94100 – Saint Maur-des-Fossés, France.
[h] Carophyll® pink, DSM Nutritional product, Basel, Switzerland.
[i] Carophyll® red, DSM Nutritional product, Basel, Switzerland.
[j] Means of two independent determinations.

authorized (Council Directive No. 70/524/EEC and Council Regulation (EC) No. 1831/2003). Diets were pelleted using a steamless pelleting machine (M-Labor, Simon Heesen B.V., Boxtel, The Netherlands) through a 4.5 mm die (pellet temperature after the die ≈75 °C). Diets were stored at +4 °C prior to use. Fish were distributed at random among 2 m diameter cylindrical fibreglass tanks receiving flow-through spring water (constant temperature, 17 ± 1 °C; pH, 7.4; $Cl^-$, 22.5 mg/l; $Ca^{2+}$, 75 mg/l; dissolved oxygen, 8 mg/l) at a rate of 5 volume changes per hour. Tanks received a natural photoperiod (February to May). Fish were hand-fed twice daily (8:30, 16:30 h) to apparent satiation and complete feed ingestion was assessed visually.

At the end of the 100 day feeding period 40 fish (mean weight: 1 kg) per diet group were slaughtered, bled by cutting the gill, rapidly chilled in ice slurry, and kept in ice prior to processing. They were filleted manually the next day. Each fillet was placed individually into a plastic bag in ice, then transported to Agrotec (travel time 2 h) where they were cooked.

### 2.2. Processes, sampling

The following cooking treatments were used: moist heat- and dry heat-cooking. For both treatments, fish fillets were placed skin side down on individual aluminium trays, securely covered and processed in an atmospheric combination oven with revolving heat (Combi ClimaPlus® FCP, Frima GmbH, Frankfurt am Main, Germany). For moist heat-cooking, a steam generator produces hygienic steam and releases it into the cooking cabinet where it circulates at high speed. For dry heat-cooking, heating elements heat the dry air which circulates evenly throughout the interior inside the cabinet. The duration of heating for the two cooking methods (8 min for moist heat-cooking at 100 °C, and 12 min for dry heat-cooking at 180 °C, respectively) was determined as the amount of time required to reach a fish fillet core temperature of 70 °C (Johanssen, 2001). Sensors covering various measuring points of the core allowed checking of the core temperature at any time to regulate the cooking process.

Fish fillet firming was accomplished by leaving the cooked fillets in a cold room at +4 °C for 2 h (Council Regulation (EC) No. 852/2004). Total weight of the samples after cooking was measured. Fish fillets were then individually placed under vacuum in plastic pouches (Linvac 80, Linpac plastics Pontivy S.A., Pontivy, France), using a vacuum packaging machine (mod Galaxy AG 800, Multivac France sarl, Marne-la-Vallée, France). The moisture and oxygen permeabilities of this pouch were 5 g/m$^2$/24 h (at 25 °C, 90% relative humidity RH), and 45 cm$^3$/m$^2$/24 h (at 23 °C, 50% RH), respectively, according to the manufacturer. The packaged samples were then deep-frozen in a cryogenic freezing cabinet (Silversas™, Air Liquide S.A., Paris La Défense, France), and were stored at −20 °C in the dark until used for analyses.

### 2.3. Analytical methods

Analyses of fish fillet weight, fillet colour, and fillet biochemical contents (moisture, canthaxanthin, astaxanthin, total lipid) were carried out on each sample.

Muscle colour was assessed, before and after cooking, by using a chromameter (CR200, Minolta Camera Ltd, Osaka, Japan) equipped with an 8 mm dia aperture and calibrated on a white reference ceramic plate before use, as described by Choubert, Blanc, and Vallée (1997). Samples were scanned at three locations along the fillet: anterior (close to the head), mid-region, and posterior (close to the tail) sections to determine the average $L^* a^* b^*$ values as the averages of the three measurements. All measurements were expressed in colorimetric space, $L^* a^* b^*$, in accordance with the recommendations of the Commission Internationale de l'Éclairage (CIE, 1976). In this colorimetric space, "$L^*$" describes lightness (black = 0, white = 100); "$a^*$" intensity in red ($a^* > 0$), and "$b^*$" intensity in yellow ($b^* > 0$). The two chromatic attributes: hue angle ($H$ (°)$_{ab}$ = arctan $b^*/a^*$), the hue of the colour (red = 0°, yellow = 90°) and chroma ($C^* = (a^{*2} + b^{*2})^{1/2}$) were calculated according to Wyszecki and Stiles (1967).

Chemical analyses of trout fillets were as follows: moisture after drying for 24 h at 105 °C (Oven ULE 500, Memmert gmbh, Schwabach, Germany) (AOAC, 1990), total lipids by a gravimetric method after solvent extraction (Folch, Lees, & Sloane Stanley, 1957), astaxanthin and canthaxanthin, measured spectrophotometrically after solvent extraction (Guillou, Choubert, & de la Noüe, 1993).

The carotenoid retention factor was used and weight yield and retention factors were calculated as follows (Murphy, Criner, & Gray, 1975):

$$\text{Weight yield } \% = (\text{Weight of fillet after cooking in g} / \text{weight of fillet before cooking in g}) \times 100$$

$$\text{Carotenoid retention } \% = (\text{Content of carotenoid per 100 g of fillet after cooking} / \text{Content of carotenoid per 100 g of fillet before cooking}) \times \text{Weight yield}.$$

### 2.4. Statistical analysis

Statistical differences between treatment groups were determined for all of the chemical and physical tests. Means were