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Effect of storage on oxidative quality and stability of extruded astaxanthin-coated fish feed pellets

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ABSTRACT

This study examined the stability of extruded and astaxanthin-coated fish feed pellets during storage in a light box at 28 °C and 620 lx. Seven groups of fish feed pellets were vacuum coated with fish oil that contained levels of astaxanthin ranging from 0 to 100 ppm. To equalize differences in the conditions for the fish feed pellets inside the light box, the samples were systematically circled during the experimental storage period of 183 days. The degradation of astaxanthin was monitored using multi-spectral images, captured 28 times in the course of the storage period. Additionally, samples were collected at storage day 8, 15, 22, 92 and 183 for chemical determination of the astaxanthin concentration. The degradation of astaxanthin was shown to primarily be affected by light and limited to occur at the surface of the fish feed pellets, whereas the astaxanthin embedded in the core of the pellets was comparatively protected against degradation. Furthermore, the initial concentrations of astaxanthin influenced the degradation *per se*, signifying self-protective properties of astaxanthin.

1. Introduction

Flesh pigmentation, along with freshness, is well-known to be the major quality parameter when evaluating the properties of salmonids for human consumption (Torrissen and Naevdal, 1988; Torrissen and Christiansen, 1995). Astaxanthin is the primary pigment accounting for the natural red colour of wild salmon, lobster, crab and shrimp. Commercially produced astaxanthin is the carotenoid pigment used in fish feed for the salmonid aquaculture industry (Sigurgisladottir et al., 1994). When farmed, the fish are supplied with pigment through the diet in concentrations ensuring a desired colour profile of the flesh at slaughtering. The right degree of flesh pigmentation is of great economic importance for the individual farmer (Torrissen, 1985), wherefore the requirements for the feed producers regarding pigmentation efficiency and predictability are strict. Astaxanthin is exposed to a range of harsh conditions during processing and storage of feed, including heat, light

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Table 1
Astaxanthin concentration in coating oil and grouping of 35 samples.

Dilution	Fraction of K7	Group name	Sample ID
0 ppm	0	K1	1–5
5th dilution	1/32	K2	6–10
4th dilution	1/16	K3	11–15
3rd dilution	1/8	K4	16–20
2nd dilution	1/4	K5	21–25
1st dilution	1/2	K6	26–30
100 ppm	1	K7	31–35

and oxygen, which all have influence on the final concentration of astaxanthin in the fish feed (Marleen, 2007; Armenta and Guerrero-Legarreta, 2009; Franco-Zavaleta et al., 2010; Anarjan and Tan, 2013). The deposition rate of astaxanthin in the flesh is known to be less effective as the astaxanthin concentration in the feed is increased; yet, the overall deposition is found to be larger for feed with high concentrations of astaxanthin (Choubert and Storebakken, 1989; Hencken and Estermann, 1991). Previously, astaxanthin was added directly to the meal mix prior to extrusion of the fish feed. As a result of the high extrusion temperature, nearly 50% of the astaxanthin was lost in this step of the process alone (Hencken and Estermann, 1991). Nevertheless, absence of antioxidants during extrusion can result in formation of free radicals (Schaich, 2002). Even though the harm of the radicals is limited in the extruder, they can initialize the oxidation of lipids and valuable nutrients, which are added in the subsequent coating, and thereby reducing the oxidative stability of the feed. Reduced oxidative stability of fish feed is known to affect the growth and health of the fish as well as their nutritional quality (Hernández et al., 2014).

Historically, astaxanthin is a very expensive feed additive, and considering the negligible mass fraction posed in the recipes for salmonid feed, it nevertheless made up for 10–15% of the total feed costs in the early 1990s (Johnson and An, 1991). Even though price of astaxanthin has decreased considerable within the recent years, determination of astaxanthin losses during processing, handling and storage of the feed are of outmost interest for prediction of the ability of fish feed to colour the flesh of fish.

Today, the general practice of astaxanthin inclusion is to dispense astaxanthin with fish oil and subsequent coat the fish feed pellets with the mixture. This process reduces heat-related losses during extrusion. The method of coating for the incorporation of pigment into the feed places specific demands to the pellets' ability to protect and preserve astaxanthin. The aim of this study is to investigate the stability of extruded and astaxanthin-coated fish feed pellets during storage, and to evaluate the self-protective properties of the pellets. Inspired by Boon et al. (2010), the pellet structure can, from the perspective of the components in the coating fraction and the fish as the recipient, be seen as a delivery system for the valuable and fragile feed ingredients, including astaxanthin. Recently, Anarjan and Tan (2013) examined the effects of temperature, atmosphere and light on the stability of astaxanthin nano-dispersions during storage. They prepared the samples as emulsions and stored them in glass vials. Regardless of the easy reproducibility, this setup is less representative to actual conditions present during storage of astaxanthin-containing food and feed products. Thus, the surrounding matrix and its possible interference or properties as a delivery system are not considered. Therefore, evaluation of astaxanthin stability in feed pellets should be investigated in the relevant matrix in contrast to the proposed glass vial approached by Anarjan and Tan (2013).

2. Material and methods

2.1. Materials, apparatus and observations

2.1.1. Materials

Seven groups of fish feed pellets, each containing five samples, were coated with different concentrations of astaxanthin. The in total 35 samples were systematically arranged in a storage box with controlled continues light for 183 days. Each sample contained 40 g of extruded pellets, originating from the same batch of fish feed. The fish feed pellets were produced using a commercial twin-screw extruder (Clextral BC45, Clextral, France) under normal commercial conditions set to a pellet size of 4.5 mm. Despite natural present antioxidants in the meal mix, 100 ppm of ethoxyquin (Impexquin 6S, Art.: 05210000, Impextraco, Belgium) was added to the recipe. After extrusion, the group of pellets were vacuum coated (cf. section 2.1.2. *Coating Procedure*) with fish oil containing different concentrations of synthetic cold water dispersible astaxanthin (Lucantin® Pink CWD, Art.: 51027961, BASF, Germany). The highest concentration of astaxanthin was 100 ppm and was used for the group named K7. The coatings used for group K2-K6 were produced by dilution of K7 with fish oil, so the concentration of astaxanthin each time was diluted to the half of the previous concentration. Group K1 was coated with pure fish oil and is defined to contain 0 ppm of astaxanthin (Table 1). Astaxanthin is commonly measured in ppm, and relates to mass, so ppm corresponds to milligram per kilogram. After production, the pellets were stored for two months in vacuum-packed plastic bags at 2 °C in a dark environment to minimize the oxidation process prior to the illuminated 183 days in the storage box. The two months of pre-storage were necessary to solve logistical and executional challenges across academia and industry.