Animal Feed Science and Technology 223 (2017) 42–52

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

The enrichment of chicken meat with omega-3 fatty acids by dietary fish oil or its mixture with rapeseed or flaxseed—Effect of feeding duration
Dietary fish oil, flaxseed, and rapeseed and n-3 enriched broiler meat

P. Konieczka*, M. Czauderna, S. Smulikowska

The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Jabłonna, Poland

ARTICLE INFO

Article history:
Received 11 May 2016
Received in revised form 17 October 2016
Accepted 30 October 2016

Keywords:
Broiler meat
n-3 Fatty acids
Fish oil
Rapeseed
Flaxseed
Feeding duration

ABSTRACT

The consumption of chicken meat has steadily increased in recent decades, thereby making meat enriched with long-chain polyunsaturated fatty acids (LC-PUFA) an important delivery route of this nutrient to humans. This study aimed to evaluate how feeding duration of a diet with fish oil and flaxseed or rapeseed can enhance broiler meat with n-3 fatty acids (FA). One hundred and twenty-three 15-day-old female broilers Ross 308 were housed individually and randomly allocated to four groups: control (15 birds), and three experimental groups (36 birds each) that were each divided into three subgroups of 12 birds. Four diets differing in fat composition were prepared. Lard was the source of supplementary fat in diet L; in the experimental diets, fat was derived from fish oil (FO, 10 g kg^{-1} diet) and either lard (LFO), flaxseed (FFO), or rapeseed (RFO) in amounts appropriate to produce fat levels similar to those in the control diet. Diets were cold-pelleted and fed until slaughter at 36 days of age. The control group was fed the L diet throughout the study, whereas birds in the experimental groups were fed the L diet until it was substituted by the experimental diets for one, two, or three weeks preceding slaughter. The performance of all groups did not differ from the control, but within the experimental groups, LFO birds had a higher body weight gain because of higher feed intake. RFO birds had a higher thyroid weight ($P < 0.02$). The levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in breast and thigh meat lipids increased in groups fed the experimental diets as compared to the control. There were substantial increases in α-linolenic acid levels and a lower PUFAn-6/n-3 ratio in birds fed the FFO diet as compared to the RFO and LFO diets ($P < 0.001$). Results indicated that one week of feeding the experimental diets was sufficient to enrich breast meat with LC-PUFA, whereas two weeks were needed to effectively enrich thigh meat with these FA. Thus, the meat of broilers fed diets with

Abbreviations: AI, adequate intake; ALA, α-linolenic acid; BW, body weight; BWG, body weight gain; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; FA, fatty acids; FAME, fatty acid methyl esters; FCR, feed conversion ratio; FFO, flaxseed and fish oil; FO, fish oil; LA, linoleic acid; LC-PUFA, long-chain polyunsaturated fatty acids; LFO, lard and fish oil; LSD, least significant difference; MS, mass selective; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; RFO, rapeseed and fish oil; SFA, saturated fatty acids.

* Corresponding author at: The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Instytucka 3, 05-110 Jabłonna, Poland.

E-mail address: p.konieczka@ifzz.pl (P. Konieczka).

http://dx.doi.org/10.1016/j.anifeedsci.2016.10.023

fish oil and either flaxseed or rapeseed over a period of two weeks before slaughter can be labeled as "high in omega-3 fatty acids." A 100 g portion of such breast or thigh meat would provide on average 33% and 15.5%, respectively, of the recommended daily intake of EPA and DHA for humans, and therefore make enriched chicken meat a superior source of LC-PUFA than lean fish meat.

1. Introduction

Despite the general recommendation for human consumption, dietary intake of n-3 long-chain polyunsaturated fatty acids (LC-PUFA) has not increased significantly over the last decade (Givens, 2015). Adult daily intake of eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) in various countries is far below the level considered sufficient to prevent cardiovascular disease (Institute of Medicine Dietary Reference Intakes for Energy, 2005; Scientific Advisory Committee on Nutrition, 2004; WHO, 2003). Current Western diets are typically rich in plant oils and animal fats, which are rich sources of linoleic acid (LA, C18:2n-6) and alpha-linolenic acid (ALA, C18:3n-3), but deliver low amounts of EPA and DHA. Additionally, the PUFAn-6/n-3 ratio of such diets is much higher than that recommended as being optimal for human health (Gibbs et al., 2010).

Two general strategies have been developed to overcome the problem of low LC-PUFA intake. The first one is a pharmacological approach, in which the recommended intake of key fatty acids (FA) is supplied through the oral consumption of encapsulated fish oils rich in EPA and DHA. This method has the benefit of ensuring an intake of LC-PUFA that is adequate to confer health benefits (Calder, 2013; Marangoni and Poli, 2013), but the disadvantage of necessitating daily medication administration and creating considerable side effects (Shahidi, 2015). The second strategy involves the enrichment of animal-derived foods with LC-PUFA, which improves the functional value of such resources for humans, but does not rely on medicaments or changing dietary habits. More specifically, enhancing the functional value of poultry meat through dietary intervention appears to be the most justified, safe, and efficient method to accomplish this goal (Zhang et al., 2010). Poultry is widely consumed and its fat composition can be successfully enriched with PUFAn-3 by feeding chickens special diets. Therefore, significant research has been undertaken to improve the functional value of chicken meat through dietary treatments, such as substituting commercial fat blends with plant oils or oil seeds, fish oil, or a combination of these.

An improvement in the functional value of meat was documented in studies of broiler chickens in which dietary lard was replaced with flaxseed oil that was rich in PUFAn-3 (Nguyen et al., 2003). Similarly, the inclusion of 100 g kg^{-1} of rapeseed oil into a broiler diet had a positive effect on the FA composition of adipose tissue (Młodkowski et al., 2003). Feeding broilers diets containing 50 g kg^{-1} of soybean oil caused a significant improvement in the PUFA composition of abdominal fat, liver, breast, and muscle tissues compared to a group fed the same amount of fat that was instead derived from beef tallow (Scaife et al., 1994). However, despite the promising potential of plant oils to modify the FA profile of chicken meat, a key limitation of their usage is the cost of feed. Using rapeseed oil instead of soybean oil in turkey diets increased the cost of feed by 3%; when flaxseed oil was used, the cost of feed increased by 37% (Zduńczyk and Jankowski, 2013).

Alternatively, the FA profile of broiler meat may be improved by oil seeds that do not substantially increase the cost of feed. In a previous study from our laboratory (Nguyen et al., 2003), 100 g kg^{-1} of dietary rapeseed significantly increased the concentration of PUFA in the edible parts of chicken carcasses without a negative effect on performance, as compared to a group supplemented with animal fat. In the same study, a positive shift in the PUFA content of meat was achieved by dietary inclusion of 80 g kg^{-1} of flaxseed, but it was associated with decreased feed utilization and a lower meat yield. Using both oil seeds in broiler diets resulted in the enrichment of meat with PUFA, but rapeseed tended to increase the concentration of LA, whereas linseed increased the concentration of ALA. EPA and DHA concentrations remained insufficient when considering the functional properties of the meat. However, using EPA and DHA derived from fish oil is an effective method of transfering FA to the edible parts of the carcass. Nutritionally meaningful contributions of EPA and DHA to broiler meat that do not compromise sensory properties can be achieved when dietary fish oil is used at levels of up to 20 g kg^{-1} (Ribeiro et al., 2013). However, it is difficult to justify the use of pure fish oil in animal feed because of its high cost and reported exhaustion of fishery resources (Givens, 2015; Pauly et al., 2013).

Collectively, the above limitations have contributed to the lack of implementation of a dietary strategy that improves the functional value of chicken meat in commercial production. There is a need to find an economically effective practical solution for producing functional broiler meat, using easily accessible components. In this context, in contrast to many other studies we did not evaluate the potential of pure oils to enrich chicken meat with LC-PUFA, but rather studied an application of raw materials that are often accessible as a by-products. The use of such materials may offer a promising method to obtain chicken meat with functional properties, in either practical or in commercial production. Therefore, the objectives of this study were: (1) to evaluate a combination of oil seeds and rendered fish oil as a way to improve the functional value of chicken meat; and (2) to verify how long a modified diet must be administered in order to achieve nutritionally meaningful enrichment of chicken meat with EPA and DHA for human consumption.