Effect of Feeding Hens Regular or Deodorized Menhaden Oil on Production Parameters, Yolk Fatty Acid Profile, and Sensory Quality of Eggs

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ABSTRACT An experiment was conducted to investigate whether feeding menhaden oil (MO) to hens affects egg weight, and whether using deodorized MO (DMO) could ameliorate decreased sensory quality of eggs (characteristic for hens fed high fish oil diets). Two-hundred twenty-four Single Comb White Leghorn hens were allocated to seven dietary treatments comprising either no fish oil, DMO, or regular MO (RMO) at 2, 4, and 6% in commercial-type diets from 19 to 55 wk of age. The data collected were analyzed in four experimental periods (i.e., 0, 2, 6, and 9 mo after feeding MO diets). The sensory evaluation of 2-wk stored eggs from hens fed the 2% RMO, 2% DMO, and control diets was undertaken. Egg weight decreased linearly with increasing MO in all periods tested ($P < 0.05$). The panelist's scores of aroma, taste, flavor, and acceptability of eggs from hens fed diets containing 2% of either RMO or DMO were lower ($P < 0.05$) than for control eggs. Greater aftertaste and off-flavors in these eggs were also detected. No differences in sensory quality ($P > 0.05$) for eggs from hens fed RMO vs. DMO were found. These results suggest that the deodorization of MO does not ameliorate the impaired sensory quality of eggs characteristic of hens fed MO.

(*Key words*: omega-3, omega-3 eggs, menhaden oil, deodorized menhaden oil, egg sensory quality)

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INTRODUCTION

Over the last 20 yr, evidence from epidemiological studies and clinical trials in humans and animals has emphasized the role of omega-3 fatty acids (n-3) in decreasing the risk of heart disease and neural development (Caggiula and Mustad, 1997). Barlow et al. (1990) suggested that Western diets should contain 3 g total n-3/d, of which at least 1 g should be derived from long-chain n-3 [LCn-3; eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), or docosahexaenoic acid (DHA)]. Health and Welfare Canada (1990) suggested an n-6:n-3 ratio of 4:1 in human diets. In contrast, the average total n-3 consumption is 1.7 g/d, and the n-6:n-3 ratio ranges between 10:1 and 20:1 (Barlow et al., 1990). Gibney (1997) estimated the average n-3 total consumption in 10 states in the USA to be 0.68 g/d. Thus, the possible n-3 deficiency in the current Western diet has stressed the need for alterations in the patterns of consumption of these lipids (Department of Health, 1994), and the consumer's desire for healthier foods has in fact increased the demand for such products (Marshall et al., 1994).

The inclusion of n-3 into yolk lipids is feasible and achieved by feeding diets rich in n-3 to hens (Caston and Leeson, 1990). Fish oils are common feed ingredients used to increase yolk LCn-3 in layers, and menhaden oil (MO) has been used most frequently (Leskanich and Noble, 1997). Feeding MO to birds results in a proportional increment of LCn-3 in eggs. However, several researchers have reported impaired production parameters in hens fed fish products, and particularly reduced egg weight (Van Elswyk et al., 1992, 1995; Whitehead et al., 1993; Marshall and Van Elswyk, 1994). However, such reports have not been confirmed by others (Yu and Sim, 1987; Hargis et al., 1991; Nash et al., 1996). The lack of long-term studies could explain some of these discrepancies.

An impaired sensory quality has also been observed in eggs from hens fed >1.5% MO (Van Elswyk, 1997b). The main off-flavor of eggs produced by feeding fish products to hens has been described as "fishy" by panelists. Volatiles seem to play an important role in the formation of odors and off-flavors in n-3-enriched eggs. Van Elswyk et al. (1995) found that volatile compounds of low, rather than high, molecular weight increased in eggs from hens fed MO, and of the 42 volatiles tested, 23 were influenced by dietary MO.

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Abbreviation Key: DHA = docosahexaenoic acid; DMO = deodorized menhaden oil; DPA = docosapentaenoic acid; EPA = eicosapentaenoic acid; LCn-3 = long-chain n-3 fatty acids; MO = menhaden oil; n-3 = omega-3 fatty acids; RMO = regular menhaden oil.

TABLE 1. Diet compositions (g/kg)

	Diets[1]						
Ingredients	1	2	3	4	5	6	7
Corn	391.0	391.0	391.0	391.0	391.0	391.0	391.0
Soybean meal	236.6	236.6	236.6	236.6	236.6	236.6	236.6
Wheat middlings	200.0	200.0	200.0	200.0	200.0	200.0	200.0
Limestone	86.6	86.6	86.6	86.6	86.6	86.6	86.6
Animal-vegetable fat	60.0	40.0	20.0	. . .	40.0	20.0	. . .
Dicalcium phosphate	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Salt	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Vitamin-mineral premix[2]	7.5	7.5	7.5	7.5	7.5	7.5	7.5
DL-methionine	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Regular menhaden oil[3]	. . .	20.0	40.0	60.0	. . .	. . .	. . .
Deodorized menhaden oil[3]	. . .	. . .	. . .	. . .	20.0	40.0	60.0
Analyzed fatty acid composition							
C18:3n3, LNA[4]	2.39	1.66	1.8	1.9	1.62	1.57	1.64
C20:5n3, EPA[5]	0	3.88	7.47	10.59	4.02	7.39	10.03
C22:5n3, DPA[6]	0	1	1.07	1.6	0.46	1.15	1.66
C22:6n3, DHA[7]	0	1.43	2.62	3.73	1.2	2.07	2.55
Total omega-3	2.39	7.97	12.96	17.82	7.3	12.18	15.88
Total omega-6	20.62	18.25	17.7	17.8	19.06	17.59	17.4

[1]Calculated analyses: ME, 2,941 kcal/kg; CP, 18%; fat, 8.44%; calcium, 3.7%; available phosphorus, 0.42%; methionine, 0.37%; and lysine, 0.97%.

[2]Provides per kilogram of diet: vitamin A, 8,000 IU (retinyl palmitate)l cholecalciferol, 40 μg; vitamin E, 11 IU (dl-α-tocopheryl acetate); riboflavin, 9.0 mg; biotin, 0.25 mg; pantothenic acid, 11.0 mg; vitamin B_{12}, 13 mg; niacin, 26 mg; choline, 900 mg; vitamin K, 1.5 mg; folic acid, 1.5 mg; ethoxyquin, 125 mg; manganese, 55 mg; zinc, 50 mg; copper, 5 mg, 30 mg; and selenium, 0.1 mg.

[3]Omega Protein Inc., Reedville, VA 22539.

[4]LNA = linolenic acid.

[5]EPA = eicosapentaenoic acid.

[6]DPA = docosapentaenoic acid.

[7]DHA = docosahexaenoic acid.

Deodorization is a high-temperature, high-vacuum, steam-distillation process that eliminates volatile odor and flavor materials by partial removal and thermal destruction so that the deodorized oil will not impart any flavor to the final food product (Dudrow, 1983). Lin et al. (1990) reported that deodorization removed most of the alcohols contained in crude menhaden oil and 96 to 99% of the aldehydes. These workers also reported that deodorization was very effective in removing ketones and benzene-containing compounds. Such volatiles play a role in the formation of fishy odors and flavors in foods (Karahadian and Lindsay, 1989; Kawai, 1996), and some of them have been related to the presence of fishy aromas and tastes in eggs from hens fed MO (Van Elswyk et al., 1995).

The current experiment was designed to 1) evaluate hen performance, and particularly egg weight, in birds fed MO and 2) to evaluate the sensory quality of eggs from birds fed either regular (RMO) or deodorized MO (DMO).

MATERIALS AND METHODS

Two-hundred twenty-four Single Comb White Leghorn Shaver pullets were obtained at 19 wk of age. Birds were housed individually in laying cages in a room maintained at 20 C under a photoperiod of 14 h light:10 h darkness. Substitutions of animal-vegetable blend fat with either RMO or DMO[3] at 2, 4, or 6% were carried out in order to prepare seven experimental diets (Table 1), including a control diet without any fish oil. The RMO and DMO were stored at −20 C until diet preparation, and the fish oils contained 1,000 ppm of GT-1[3] (mixed tocopherols) as an antioxidant. The experimental diets were prepared at the University feed mill. The birds were allocated to one of the seven dietary treatments, each being represented by eight replicates comprised of four individually and adjacently caged hens fed as a group. Birds were fed these diets ad libitum until the end of the experiment. The experimental phase consisted of nine periods of 28 d each. Body weight was recorded at the beginning (19 wk of age) and end of the experiment (55 wk of age). Egg production was recorded continuously throughout the experiment. Feed intake was measured for Periods 2, 6, and 9, and was calculated as the mean feed consumed by each four-bird replicate during the last 48 h of each period. Egg weight, egg production, eggshell deformation, and Haugh units were measured for eggs collected on the last 2 d of Periods 2, 6, and 9. Dietary fatty acids were extracted from eggs for further analysis using the method of the Association of Analytical Chemists (Number 920.39; Association of Official Analytical Chemists, 1990). At the end of Period 6, eggs were collected and six yolks per replicate were pooled prior to chemical analysis. Duplicate yolk samples were processed according to the methods described by Folch et al. (1957) for extraction of fatty

[3]Omega Protein Inc., Reedville, VA 22539.

TABLE 2. Production parameters of hens fed either regular or deodorized menhaden oil

Treatment no.	Menhaden oil (%)		Body weight gain (g) 19 to 55 wk of age	Feed intake (g/hen per d) per period			Egg production (%) per period			Egg weight (g) per period			Egg mass (g/egg per d)[1] per period		
	Regular	Deodorized		2	6	9	2	6	9	2	6	9	2	6	9
1	. . .	. . .	437	101	104	109^{ab}	93	95	92	54.1^{a}	60.3^{a}	63.5^{ab}	50.4^{ab}	57.4	58.4^{ab}
2	2	. . .	403	100	102	107^{abc}	94	95	90	53.3^{abc}	60.4^{a}	63.9^{a}	49.9^{ab}	57.5	59.5^{a}
3	4	. . .	369	96	98	100^{bc}	91	93	86	52.3^{bc}	57.8^{bc}	62.0^{bc}	47.5^{b}	53.6	54.3^{b}
4	6	. . .	365	94	103	105^{abc}	90	93	89	51.7^{b}	58.2^{bc}	62.1^{bc}	47.0^{b}	55.3	55.2^{ab}
5	. . .	2	461	98	101	110^{a}	96	93	90	53.1^{abc}	59.1^{ac}	62.8^{ab}	51.4^{a}	56.9	56.2^{ab}
6	. . .	4	440	94	97	99^{c}	94	94	88	51.8^{bc}	58.7^{ac}	62.8^{ab}	48.5^{ab}	56.7	55.0^{ab}
7	. . .	6	423	97	102	101^{abc}	94	93	87	52.4^{abc}	58.9^{ac}	62.4^{ab}	48.7^{ab}	55.4	54.5^{b}
P			NS[2]	NS	NS	**	NS	NS	NS	**	**	*	**	NS	**
SE			29	2	2	3	1	2	2	0.4	0.5	0.6	1.1	1.1	1.1

[a–c]Values followed by different letters within columns are significantly different.

[1]Egg mass/hen per d = (egg weight × egg production)/100.

*$P < 0.05$.

**$P < 0.01$.

[2]NS = Not significantly different ($P > 0.05$).

acids. Methyl esters of feed and yolk fatty acids were obtained using Meth-Prep® II transesterification reagent,[4] and subsequent fatty acids profiles were obtained by gas-liquid chromatography. The methyl esters were analyzed using a 30-m × 0.25-mm inside diameter and 0.5-μm coding DB-225 J and W Scientific column[5] installed on a Varian 3400 gas-liquid chromatograph with a flame ionization detector.[6] Retention times were compared with known standards.[7] In calculating the n-3 yolk content, no further corrections were made to account for the portion of the gravimetric fat that is not represented by fatty acids.

Sensory evaluation was conducted with hardboiled eggs. In a preliminary study carried out to select treatments for sensory evaluations, four of six untrained panelists strongly objected to eggs from hens fed 4 or 6% of either RMO or DMO due to their strong aroma, which was described as "fishy." Given these results, we decided to include only the treatments comprising 2% of either RMO or DMO, together with the control group (Treatments 1, 2, and 5, respectively) in subsequent taste panel studies.

Eggs were collected and kept at 5 C for 14 d to facilitate peeling. Eggs were boiled for 15 min and kept in water at around 35 C to keep them warm until they were served for sensory evaluation (Caston and Leeson, 1990). Thirty-five untrained panelists were asked to evaluate warm hardboiled eggs after cutting them in half. Unsalted crackers and water were offered as carriers. Each panelist was presented with three peeled eggs individually placed in closed plastic containers corresponding to Treatments 1, 2, and 5 (control, 2% RMO, and 2% DMO, respectively). Each egg was randomly placed and labeled using three-digit randomized numbers. The surveys presented to panelists included brief instructions and a short definition of each attribute. The attributes tested and the definitions provided to panelists were: a) aroma: odor of the whole egg, b) taste: the sensation produced on the tongue and palate by the yolk taken into the mouth, c) aftertaste: the sensation that lingers on the tongue and palate after swallowing, d) flavor: the distinctive aroma and taste of the yolk (i.e., an integrated sensation), e) presence of off-flavors: any rejective or unusual smell or taste of the yolk, and f) overall acceptability. Panelists were ask to score, on a 15-cm line, their dislikes or likes (0 to 15) for aroma, taste, flavor, and acceptability, and their perception of off-flavors and aftertastes (from absent = 0 to very strong = 15). Panels were carried out in a room at 23 C, separate from the cooking area and under red light to avoid visual differences in yolk color. The taste panels were scheduled from 1000 to 1200 h and 1400 to 1600 h Thursdays and Fridays. Each panelist was asked to perform the evaluations once a wk for 2 consecutive wk.

Statistical Analysis

The experiment was a completely randomized design with replicate as the experimental unit. A one-way ANOVA was used to test the effects of dietary treatments. Those response variables having a significant F test ($P < 0.05$) were further analyzed using Tukey's test. Linear effects were tested for different levels of MO included for different variables using orthogonal contrasts. Further regression analysis was carried out for those response variables having a significant linear effect ($P < 0.05$; Steel et al., 1997). For sensory evaluation, the numerical expression analyzed was derived by measuring the distance between the starting point (zero) of the 15-cm line and the actual mark of the panelists preferences for each egg (cm). The experimental unit was each egg tested. The data were collected and analyzed as a mixed linear model. Tukey's test was performed for comparison among treatments when variables were significant.

[4]Alltech Associates Inc., Deerfield, IL 60015-1899.

[5]J & W Scientific, Folson, CA 95630-4714.

[6]Palo Alto, CA 94304.

[7]Nu-Chek-Prep, Inc., Elysian, MN 56028.

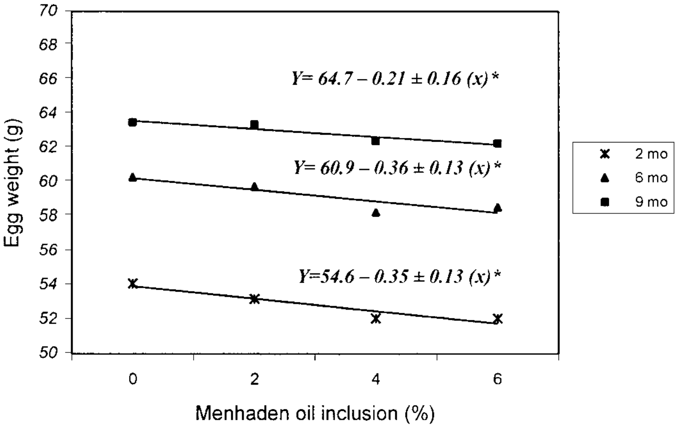

FIGURE 1. Egg weight for hens fed menhaden oil for 2, 6, and 9 mo; *$P < 0.05$.

RESULTS

The calculated proximate analyses and determined n-3 profile of the experimental diets are shown in Table 1. The n-3 content of the diets increased as MO increased in the diet, although slightly lower concentrations of DHA were found in diets containing DMO vs. RMO. The results of the production parameters are presented in Table 2. Body weight gain from 19 to 55 wk of age was not affected by the dietary treatments ($P > 0.05$). The treatment effect on feed intake was not significant in Periods 2 or 6. However, in Period 9 birds fed 4% DMO had lower feed intakes compared with those fed 2% DMO or the control diet. Egg production was not affected by treatments at any period ($P > 0.05$, Table 2).

Dietary MO influenced egg weight in all periods tested. The effect of feeding either RMO or DMO on egg weight was tested by orthogonal contrasts and found to be linear and similar for RMO and DMO (data not shown). Consequently, a linear regression analysis was carried out for each period considering the overall effect of MO (RMO + DMO) on egg weight (Figure 1). Birds fed MO laid eggs 0.35, 0.36, and 0.21 g lighter for each 1% of MO included in the diet for Periods 2, 6, and 9, respectively. As a consequence of this effect, egg mass followed the same linear trend in Periods 2 and 9 (Table 2).

The n-3 concentrations of eggs increased as a result of feeding MO ($P < 0.01$, Table 3). In birds fed either 2% RMO or 2% DMO, linolenic acid content was not affected. However, in birds fed 4 or 6% of either RMO or DMO, linolenic acid content of eggs increased significantly ($P < 0.01$). This increment was more notable in birds fed RMO than in those fed DMO. The egg concentrations of EPA, DPA, and DHA increased as a result of feeding hens either RMO or DMO ($P < 0.01$, Table 3). This increase was similar for hens fed RMO or DMO at 2 or 4%. However, at 6% of dietary inclusion, the birds fed RMO produced eggs with greater concentrations of EPA, DPA, and DHA compared with those fed DMO.

Feeding diets containing DMO at 2% decreased panelists' scores of sensory attributes of eggs (Tables 4 and 5). Higher scores were given to control eggs in all attributes tested ($P < 0.02$). The same effect was observed in eggs from hens fed RMO. Panelists generally did not differentiate between eggs from DMO- or RMO-fed hens ($P > 0.05$). The panelists' perceptions of aftertaste and off-flavors of eggs from hens fed DMO vs. the control diet were significantly higher ($P < 0.02$). The panelists' scores for the presence of aftertaste and off-flavors of eggs from hens fed RMO vs. DMO were not different. However, the perception of aftertaste of eggs from hens fed control diet vs. RMO was not different ($P > 0.05$).

The most frequent adjective used by panelists to describe the sensory attributes of MO eggs was "fishy." Panelists referred to eggs from hens fed RMO and DMO as being "fishy" 13 and 11 times, respectively, within the 35-person group. In contrast, the same reference was made to control eggs only four times.

DISCUSSION

Including MO in commercial layer diets does not usually affect body weight gain, feed intake, or egg production (Hargis et al., 1991; Leeson and Summers, 1997). In the current experiment, feed intake was affected in hens fed DMO in Period 9. During the formulation of the exper-

TABLE 3. Omega-3 fatty acid concentrations and calculated content of eggs from hens fed either regular or deodorized menhaden oil (% yolk fat and mg/50 g egg, respectively)[1]

Dietary menhaden oil		Linolenic acid		Eicosapentaenoic acid		Docosapentaenoic acid		Docosahexaenoic acid		Total omega-3	
Regular	Deodorized	%	mg	%	mg	%	mg	%	mg	%	mg
(%)											
. . .	. . .	0.52^{c}	26	0.0^{e}	0	0.01^{e}	1	0.52^{d}	26	1.04^{f}	53
. . .	2	0.52^{c}	26	0.26^{d}	13	0.14^{d}	7	1.71^{c}	85	2.63^{e}	131
. . .	4	0.76^{b}	38	0.62^{c}	31	0.29^{c}	15	2.46^{b}	123	4.13^{d}	207
. . .	6	1.16^{a}	58	1.21^{a}	61	0.56^{a}	28	3.90^{a}	196	6.83^{c}	343
2	. . .	0.45^{c}	23	0.30^{d}	16	0.17^{d}	9	1.74^{c}	87	2.65^{e}	134
4	. . .	0.59^{bc}	30	0.60^{c}	30	0.29^{c}	15	2.27^{bc}	114	3.74^{b}	188
6	. . .	0.74^{b}	37	0.89^{b}	45	0.41^{b}	21	2.87^{b}	144	4.91^{a}	246
P		0.001		0.001		0.001		0.001		0.001	
SE		0.08		0.09		0.06		0.30		0.17	

[a–f]Values followed by different letters within columns are significantly different ($P < 0.01$).

[1]Considering a total fat content of 1.65 g/50 g egg.

TABLE 4. Evaluation of sensory attributes of hardboiled eggs from hens fed regular or deodorized menhaden oil[1]

	Menhaden oil				
Attributes	Control, 0%	Regular, 2%	Deodorized 4%	P	SE
Aroma	10.2^{a}	9.1^{b}	8.9^{b}	0.02	0.4
Taste	10.4^{a}	7.5^{b}	7.5^{b}	0.0001	0.4
Flavor	10.1^{a}	7.6^{b}	7.0^{b}	0.0001	0.5
Acceptability	10.4^{a}	7.8^{b}	7.4^{b}	0.0001	0.5

^{a,b}Values followed by different letters within rows are significantly different (P < 0.02).

[1]Range: dislike = 0, like = 15.

imental diets, animal and vegetable fat was substituted directly for experimental fish oil on the assumption that they had the same ME. It is possible that DMO had a slightly higher ME value than did animal and vegetable fat or RMO, which may account for the decreased feed intake in Period 9. This effect was not tested.

Changes in egg weight associated with dietary n-3 have been reported previously (Whitehead et al., 1993; Marshall and Van Elswyk, 1994; Van Elswyk et al., 1994; Herber and Van Elswyk, 1996; Ayerza and Coates, 1999). Van Elswyk (1997a) suggested that a decrease in circulating tryglycerides of birds due to n-3 consumption could limit the availability of lipids for yolk formation. The author also suggests that n-3 could affect circulating estradiol. These effects could partially explain the lower egg weight and egg mass found in birds fed MO in this experiment. However, in the present study, the reduced feed intake observed in hens fed MO vs. the control diet could have also played a role. Other workers found no effect of feeding n-3 enriched diets on these parameters (Yu and Sim, 1987; Hargis et al., 1991; Nash et al., 1996).

The changes in yolk n-3 shown here due to feeding graded levels of MO (Table 3) are in agreement with previous reports (Adams et al., 1989; Huang et al., 1990; Van Elswyk et al., 1995; Van Elswyk, 1997a). The most significant effect of dietary MO was on LCn-3. In spite of the higher concentrations of EPA vs. DHA in MO (consistent with the n-3 content of experimental diets shown in Table 1), eggs showed a significant DHA accretion. This effect may be due to the layers' inherent n-3 metabolism, in which conversion of DHA into EPA may occur, and is due to the difference in the rate of accretion among various LCn-3 (Herber and Van Elswyk, 1996). The highest total n-3 found in birds fed 6% RMO vs. those fed 6% DMO was a consequence of the differences among n-3 profiles of experimental diets. The efficiency of deposition of LCn-3 [LCn-3 fed per day /(egg LCn-3 content × egg mass per day)] ranged between 15.5 and 19.5% regardless of the MO dietary concentration.

The association between low sensory quality of eggs and dietary fish oils has long been recognized (Holdas and May, 1966). In general, in the current trial the inclusion of 2% dietary MO decreased the sensory quality of hard-boiled eggs. This finding is in agreement with other researchers; a decreased acceptability has been reported in eggs from hens fed diets containing >1.5% MO (Koehler and Bearse, 1975; Van Elswyk et al., 1995). The sensory evaluation of eggs from hens fed DMO has not been reported before. Some authors have proposed that the use of good-quality n-3 sources in poultry diets could partially ameliorate these organoleptic problems (Van Elswyk et al., 1995; Leskanich and Noble, 1997). In the current experiment, feeding hens DMO did not improve the panelists' preferences for these eggs compared with eggs from birds fed RMO. Panelists found no difference in perception of aftertaste and off-flavors in eggs from hens fed DMO vs. RMO. As mentioned above, volatiles are associated with objectionable flavors in eggs, and they are significantly reduced in fish oils after deodorization. The oils used for this study were high-quality oils, contained preservatives, and were frozen until use, and hopefully these characteristics decreased the possibility of the formation of volatiles. However, the process of deodorization did not prevent problems of sensory quality, even with just 2% DMO in the birds' diet.

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TABLE 5. Evaluation of off-flavors and aftertastes of hardboiled eggs from hens fed regular or deodorized menhaden oil[1]

	Menhaden oil				
Attributes	Control, 0%	Regular, 2%	Deodorized, 4%	P	SE
Aftertaste	6.3^{b}	7.5^{ab}	8.2^{a}	0.02	0.5
Off-flavors	3.9^{b}	6.5^{a}	6.9^{a}	0.0001	0.6

^{a,b}Values followed by different letters within rows are significantly different (P < 0.02).

[1]Range: absent = 0, very strong = 15.

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