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ORIGINAL ARTICLE

Effect of designer diets on egg yolk composition of 'White Leghorn' hens

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Abstract A study was made on 96 'White Leghorn' hens on the influence of designer diets enriched with omega-3 fatty acids and antioxidants from natural sources on egg yolk composition. The birds were divided into four equal groups viz. Control (without enrichment); FSE − (150 g flaxseeds + 200 mg vitamin E + 3 g spirulina/kg diet); FOSe (20 g fish oil + 0.2 mg organic Se (Sel-Plex) + 3 g spirulina/kg diet) and FSE + FOSe (75 g flaxseed + 10 g fish oil + 100 mg vitamin E + 0.1 mg organic Se + 3 g spirulina/kg diet). All three designer diets increased ($p < 0.01$) the yolk carotenoid pigments and omega-3 fatty acid levels with proportionate reduction in saturated fatty acid levels and no significant change in the oleic acid levels in the yolk lipids. The three diets also reduced ($p < 0.01$) the yolk cholesterol levels. Boiled eggs from all four groups had comparable sensory acceptability. Dietary Se and vitamin E supplementation acted synergistically in increasing omega-3 fatty acid levels in the egg.

Keywords Yolk Cholesterol · Carotenoids · Omega-3 fatty acids · Se · Vitamin E

Introduction

Even though, egg is the most nutritious and relatively cheaper food, its consumption in many countries is low due to its cholesterol content. Hence, attempts have started on dietary manipulation to reduce the egg cholesterol levels. Besides, efforts are made to produce designer eggs enriched with carotenoids, omega-3 fatty acids and antioxidants. Anderson et al. (1991) improved the yolk colour by feeding spirulina. Cherian and Sim (1993), Galobart et al. (2001) and Narahari et al. (2003, 2009) enriched eggs with omega-3 fatty acids and antioxidants several fold. The present study was made to incorporate various health promoting components in egg as well as reducing the yolk cholesterol levels by feeding different functional feeds.

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Material and methods

Ninety six Forsgate strain 'White Leghorn' hens of 53 weeks age, reared in cages were randomly divided into 16 groups of six hens each. The birds were divided into four equal groups viz., (a) Control (without enrichment), (b) FSE—Layer mash containing 150 g ground full fat flaxseeds + 200 mg supplemental vitamin E + spirulina (*Spirulina platensis*) 3 g/kg diet, (c) FOSe—Layer mash containing 20 g Anchovy fish oil + organic Se (Sel-Plex) to supply 0.2 mg Se + spirulina 3 g/kg diet and (d) FSE + FOSe - Layer mash containing 75 g ground full fat flaxseeds + 10 g Anchovy fish oil + 100 mg vitamin E + 0.1 mg organic Se + spirulina 3 g/kg diet.

Four replicates were randomly allotted to each of four dietary groups. The birds were fed *ad libitum* from 53 to 58 weeks.

During the last week of the study, two eggs from each replicate were collected and the yolk samples were assayed for their cholesterol levels (Washburn and Nix 1974), crude

Table 1 Ingredients used in the experimental layer feeds (g/kg)

Ingredients	Control	FSE	FOSe	FSE + FOSe
Corn	300	250	250	250
Broken rice	170	150	210	180
Rice polish	120	–	–	–
Deoiled rice bran	–	107	107	107
Soybean meal	200	130	200	165
Sunflower meal	100	100	100	100
Dicalcium phosphate	10	10	10	10
Shell grit	98.0	97.6	97.8	97.7
Flax seed	–	150	–	75
Fish oil	–	–	20	10
Trace mineral premix	1	1	1	1
Vitamin premix	1	1	1	1
Endox (antioxidant premix)	+	+	+	+
50% vitamin E	–	0.4	–	0.2
Organic Se (Selplex)	–	–	0.2	0.1
Spirulina	–	3	3	3

protein, lipids, metabolizable energy and carotenoid pigments (AOAC 1990), fatty acid composition (Wang et al. 2000) and vitamin E (Abdollahi et al. 1993). Two samples of yolk from each replicate were analyzed for Se content using atomic absorption spectrophotometer as per the method described by Cantor et al. (2000). The sensory acceptability of hard boiled eggs from four groups were evaluated by 12 taste panelists, for colour, appearance, texture, taste, flavour and overall acceptability, using 4-point Hedonic scale (Narahari 2007). The data were subjected to analysis of variance for a completely randomized design as per the method described by Snedecor and Corchran (1989). The significance was tested using Duncan's multiple range test (Duncan 1955).

Results and discussion

The ingredient and chemical composition of the experimental layer feeds are presented in Tables 1 and 2, respectively. All three functional feeds tested reduced ($p \leq 0.01$) the yolk cholesterol levels and increased the yolk carotenoid pigments, yolk colour, vitamin E and Se levels (Table 3). The reduction in yolk cholesterol level was more than 25% which is higher than the values reported by Scheideler and Froning (1996) and Basmacioglu et al. (2001), but comparable with the results of Thiruvengadam et al. (2006) and Narahari et al. (2009). The cholesterol reduction was probably due to the combined effects of omega-3 fatty acids and antioxidants (vitamin E, organic Se and spirulina).

Table 2 Nutrient composition of experimental diets

Parameters	[a]Control	FSE	FOSe	FSE + FOSe
Crude protein, g/kg	172.0	173.5	172.3	173.2
Metabolisable energy, MJ/kg	11.1	11.1	11.1	11.1
Lipids, g/kg	32.9	46.8	45.6	46.4
Ca, g/kg	36.5	36.2	35.9	36.0
P, g/kg	7.1	7.4	7.2	7.3
[b]Lysine, g/kg	7.6	7.4	7.6	7.5
[b]Methionine, g/kg	3.6	3.6	3.7	3.8
[b]Vitamin E, mg/kg	29.2	219.8	96.6	160.2
[b]Selenium, mg/kg	0.09	0.085	0.293	0.196
[b]Total carotenoids, μg/g)	6.5	18.2	19.1	18.8

[a] Feed formulations: Refer to Table 1

[b] Calculated (Narahari 2000)

Table 3 Effect of feeds on quality of yolk

	*Control	FSE	FOSe	FSE + FOSe
Chemical				
Cholesterol, mg/g	12.9±0.03[b]	9.9±0.09[a]	9.5±0.12[a]	10.0±0.19[a]
Carotenoids, μg/g	24.5±0.12[b]	65.1±0.03[a]	65.8±0.07[a]	65.0±0.04[a]
Vitamin E, μg/g	96.8±3.77[d]	296.5±7.98[a]	169.8±6.09[c]	237.5±4.66[b]
Se, ng/g	188.0±8.29[c]	177.5±3.75[c]	420.3±6.28[a]	356.0±5.16[b]
[1]Sensory quality				
Flavour [NS]	2.3±0.42	3.2±0.17	2.5±0.34	2.6±0.33
Colour/appearance	1.8±0.48[b]	3.0±0.33[a]	3.0±0.36[a]	3.3±0.29[a]
Taste/Texture [NS]	3.0±0.42	3.5±0.29	3.5±0.28	3.7±0.27
Overall acceptability [NS]	3.0±0.23	3.2±0.21	3.0±0.23	2.9±0.13

Mean ± SD with different superscripts in a row are significantly different ($p \leq 0.01$)

* Sensory score 1 = least acceptable and 4 = highly acceptable

[1] Feed formulations: Refer to Table 1, *NS* not significant

Similar conclusions were drawn by Thiruvengadam et al. (2006) and Narahari et al. (2009).

Spirulina supplementation in functional feeds contributed to the rich orange yolk colour due to its high carotenoid pigment content. Ross and Dominy (1990) and Anderson et al. (1991) also used spirulina in hens' diet to increase yolk colour.

Vitamin E supplementation in FSE and FSE + FOSe had resulted in highly significant ($p \leq 0.01$) variations in vitamin E levels in the yolk. Jiang et al. (1994), Cherian et al. (1996) and Grobas et al. (2002) also reported a linear relationship between dietary and yolk vitamin E levels. An increase ($p \leq 0.01$) in yolk vitamin E level in FOSe, where vitamin E was not supplemented through feed but only organic Se was added, strongly suggested a synergistic and sparing action of Se to accumulate more vitamin E in the yolk. On the other hand, vitamin E supplementation (FSE) did not increase Se levels in the yolk. Similar conclusions were drawn by Thiruvengadam et al. (2006).

Organic Se supplementation in FOSe and FSE + FOSe groups resulted in an increase ($p \leq 0.01$) in egg Se levels. This finding is in line with the reports by Cantor et al. (2000), Surai and Dvorska (2000) and Narahari et al. (2005).

Boiled eggs from spirulina enriched treatments showed sensorily more ($p \leq 0.01$) acceptable yolk colour than the control (Table 3). However, other sensory attributes were comparable between treatment groups. Similar conclusions were drawn earlier by Thiruvengadam et al. (2006) and Narahari (2007).

When compared to control, omega-3 fatty acid levels increased by several folds ($p \leq 0.05$) in yolk from hens fed functional feeds (Table 4). Similar findings were reported by Galobart et al. (2001), Thiruvengadam et al. (2006) and Narahari et al. (2009). Moreover, as suggested by Narahari et al. (2005), spirulina might have acted synergistically with other omega-3 fatty acids rich flaxseeds and fish oil in increasing the omega-3 fatty acid levels in yolk.

Conclusion

Designer diets fed to 'White Leghorn' hens have produced eggs enriched with natural pigments, omega-3 fatty acids, vitamin E and Se. They also reduced significantly the yolk cholesterol levels. It is thus possible to produce health promoting value added designer eggs by manipulation of hens' diet.

Table 4 Effect of functional feeds on fatty acid composition of egg yolk lipids (g/100 g of total fatty acids)

Fatty acids	*Control	FSE	FOSe	FSE + FOSe
Myristic	0.38±0.03[c]	0.25±0.04[b]	0.19±0.02[a]	0.19±0.03[a]
Palmitic	7.5±0.11[b]	4.9±0.66[a]	5.2±0.66[a]	5.1±0.10[a]
Palmitoleic	3.6±0.07[c]	2.4±0.13[b]	2.2±0.08[b]	1.9±0.04[a]
Stearic	27.6±0.05[a]	21.7±0.36[b]	22.1±0.06[b]	20.9±0.05[b]
Oleic[NS]	44.4±0.10	43.7±1.18	44.6±0.50	43.2±0.17
Linoleic	15.7±0.05[c]	14.6±0.10[b]	15.3±0.14[c]	14.1±0.05[a]
Linolenic	0.16±0.02[c]	7.6±0.24[a]	0.39±0.02[c]	5.0±0.10[b]
Eicosapentaenoic	0.06±0.01[d]	0.08±0.02[c]	0.61±0.04[a]	0.48±0.02[b]
Docosahexaenoic	0.17±0.01[d]	0.70±0.17[c]	6.81±0.20[a]	3.69±0.14[b]

Mean ± SD with different superscripts in a row are significantly different ($p \leq 0.01$), *Feed formulations: Refer to Table 1, *NS* not significant

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