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Dietary levels of chia: influence on hen weight, egg production and sensory quality, for two strains of hens

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Abstract 1. Laying hens, 225 white and 225 brown, were fed for 90 d to compare a control diet with diets containing 70, 140, 210 and 280 g/kg chia (*Salvia hispanica* L.) seed.
2. Hen weight was not significantly affected by diet; however, manure production was less for the hens fed on chia.
3. Egg weight and production, yolk weight, and yolk percentage were determined at d 0, 30, 43, 58, 72 and 90.
4. A sensory evaluation was conducted on eggs produced during the last week of the trial.
5. No significant differences in egg production were found among treatments for the brown hens.
6. With the 280 g/kg chia diet, the white hens produced fewer and lighter eggs than did the hens fed on the control diet.
7. No significant differences were detected in yolk weight until d 90.
8. On this date the yolks produced by the white hens fed on the 70 g/kg chia diet were significantly lighter in weight, whereas the brown hens produced significantly heavier yolks, compared with the hens fed on the control diet.
9. Yolk weight as a percentage of egg weight was lower for white hens throughout the trial except on d 58 with the 140 g/kg chia diet. Significant differences, however, were detected only with the 70 g/kg chia diet on d 90 and with the 210 g/kg chia diet on d 58, 72 and 90.
10. No significant differences in taste preference or flavour were found among any of the chia treatments and the control.

INTRODUCTION

US egg consumption has declined from 256 eggs per capita per year in 1985 to 235 in 1995 (USDA, 1997). The same trend has been reported in Argentina, with annual per capita consumption declining from 160 in 1990 to 128 in 1997 (Lamelas and Asad, 1998). The decline is attributable to consumer concerns about cholesterol, fat sources, types of fatty acids consumed, and their relationship to coronary heart disease (CHD). The American Heart Association (1996) suggests limiting whole egg or egg yolk consumption to three or four per week, including those used in cooking.

Several attempts have been made to reverse the decline in egg consumption by changing egg composition through feeding hens on modified diets. Hargis (1988) reported that, in general, these efforts have produced only a modest reduction in cholesterol. Incorporation of omega-3 fatty acids in egg yolks by changing the hens' diet has been more successful, and have been reported in a number of studies (Caston and Leeson, 1990; Cherian and Sim, 1991; Caston *et al.*, 1994; Farrell, 1994; Cherian *et al.*, 1995; Nash *et al.*, 1995; Scheideler *et al.*, 1998*a*). These experiments altered the yolk fatty acid profile by adding either flax seed or fish products to the hens' feed.

Clinical investigations that have examined the effect of consumption of omega-3 enriched eggs have shown a significant decline in CHD risk factors (Oh *et al.*, 1991; Ferrier *et al.*, 1992; Sim and Jiang, 1994; Lewis *et al.*, 1998; van Elswyk *et al.*, 1998). However, the presence of an off-flavour (fishy flavour) in these eggs, which has been noted in a number of sensory evaluations especially when fish oil is used at or greater than 30 g/kg of the diet, indicates a strong marketing disadvantage (Marshall *et al.*, 1994*a*).

Ayerza and Coates (1999) used chia (*Salvia hispanica* L.) seed in a hen diet, and demonstrated that the eggs produced had a high omega-3 fatty acid content, a reduced saturated fatty acid content, low omega-6:omega-3 ratio, and no off-flavour. That earlier trial, however, utilised only one breed of hens, with chia fed at only one level. Because of the general success of

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the study, a more comprehensive trial was undertaken. An earlier paper (Ayerza and Coates, 2000) presents the results of the compositional analysis of the eggs which showed omega-3 content to increase, while cholesterol and saturated fatty acid contents decreased with the chia diets. This paper reports on egg production, hen weight, and egg sensory qualities for that trial.

MATERIALS AND METHODS

The trial was conducted under our supervision in a commercial egg production facility in San Vicente, Province of Buenos Aires, Argentina H&N laying hens (H&N International, Redmond, Washington), 225 white and 225 brown at 27 weeks of age, were selected for the study. These commercial strains were developed from White Leghorn and Red Sex Link breeds, respectively. The hens were housed three to a cage (30×45×43 cm high at the front, and 38 cm high at the back). The 5 diets contained 0, 70, 140, 210 and 280 g/kg whole chia seed. Nutrient compositions of the diets and chia seed are shown in Table 1. Each diet (treatment) was replicated 15 times, with each replicate consisting of one cage of three hens. Following random allocation to the cages, the hens were fed for 30 d prior to collecting data. The trial lasted 90 d, with the white and brown hens receiving 115 and 120 g of feed/d/hen, respectively. Water was provided *ad libitum*. Egg production was recorded throughout the trial, with all of the eggs collected and counted daily. On d 0, 30, 43, 58, 72 and 90, one egg from each of 6 random cages was selected from each treatment, individually weighed and then broken open. The yolks were separated and weighed. Fifteen hens from each treatment, one from each cage, were randomly selected on d 0 and d 90 for weighing.

Sensory evaluation

A taste test was conducted to evaluate preference and flavour. The eggs were randomly selected from those collected during the last week of the trial from both strains for the control, 70, 140 and 280 g/kg chia diets. All of the eggs were prepared in the same manner, 2 h before the taste test began. Separately, eggs from each treatment and strain, were placed in water at room temperature, brought to boiling for 5 min, then taken from the pot and placed under cold running water for 10 min. The eggs were shelled, cut longitudinally and placed in separate containers.

Eighteen untrained, unpaid adult panelists from the town of San Vicente were chosen for the test. Ten of them (5 female and 5 male) evaluated eggs from the white hens, and 8 (2 female and 6 male) evaluated eggs from the brown hens. Two separate panels were used as there were too many samples for a single panel to evaluate effectively, yet the panels were of sufficient size according to previous research. Each panelist individually received 4 small plates containing a half-egg randomly selected from each of the containers. Each plate containing eggs from the white hens was marked with either A, B, C or D, and each plate containing eggs from the brown hens was marked using W, X, Y or Z. These corresponded to the control, 70, 140 and 280 g/kg chia diets, respectively.

Panelists sat at a long table, 1 m apart, and received each of the 4 plates in random order. Each panelist had a sheet of paper with 4 numbered boxes (one for each egg) to fill in using the following alternatives for preference: like very much, like moderately, neither like nor dislike, dislike moderately, and dislike very much. Similarly, flavour was rated as: high intensity, intense, low intensity, very low intensity, and normal. For scoring and analysis purposes each classification was assigned a number from 1 to 5, respectively. Cold tap water was provided for panelists to rinse their mouths between samples.

Statistical analysis

The feeding trial was set up as a randomised block design, with the experimental unit being one cage of three hens. A treatment consisted of 45 adjacently caged hens, housed three to a cage. For the sensory evaluation a treatment consisted of either 8 or 10 eggs, white and brown, respectively, which had been randomly obtained from eggs collected from the 15 cages fed on each diet. Each variable was compared using the general linear model analysis of variance technique to assess treatment differences. When the F-value was significant ($P<0{\cdot}05$), differences in means were analysed for significance using Duncan's multiple range test (SAS Institute, 1988).

RESULTS

Egg and hen data

Results within strains

Egg production was recorded daily for each treatment and each strain. The results at d 0, 30, 43, 58, 72, 90 are presented in Table 2 along with the average egg weight, yolk weight and yolk weight percentage. At the start of the trial, significant ($P<0{\cdot}05$) differences in body weight existed between the brown hens that were to be given the 70 g/kg chia diet and those that were to be fed the other diets; however, by the end of the trial, no significant differences ($P>0{\cdot}05$)

Table 1. *Nutrient composition of laying hen diets and chia seed (dry weight basis)*

	Chia percentage in ration					
	0%	7%	14%	21%	28%	Chia seed[1]
Ingredients (g/kg of diet)						
Maize	549·1	505·9	408·5	407·3	307·9	
Soyabean pellets	254·8	228·7	166·2	194·6	154·1	
Calcium carbonate	100·8	104·3	131·6	105·3	123·9	
Meat meal	90·3	87	149·1	78·5	139·9	
Chia	0	70	140	210	280	
Vitamin complex	1·5	1·5	1·5	1·5	1·5	
Methionine	2·1	1	1·1	7	1·8	
Choline	1	1	1	1	1	
Colouring	0·4	0·4	0·4	0·4	0·4	
Nutrient content (per kg of diet)						
Analysed						
Metabolisable energy (MJ/kg)	11·7	11·7	12·1	12·6	13	13·8
Crude protein	160	160	160	160	160	171
Fibre	18·3	20	38·6	58	77·3	221
Lipids	82	95	101	135	155	328
Calculated						**Analysed**
Lysine	7·2	9·3	11·6	14	16·3	11·8
Methionine+ cystine	7·8	8	8·3	9·6	10·9	4·9
Threonine	5·4	6·9	8·7	10·5	12·3	9·1
Tryptophan	1·9	3·9	5·6	7·3	8·9	7·3
Calcium	68	76	69	60	51	5·9
Available phosphorus	7·9	9·1	8·2	6·9	5·6	8·9
Ca:P ratio	8·6	8·3	8·4	8·69	9·16	
Xanthophylls (mg/kg)	14·33	14·33	14·33	14·33	14·33	
Retinol (mg)	2·53	2·53	2·53	2·53	2·53	
Cholecalciferol (μg)	63·8	63·8	63·8	63·8	63·8	
D-alpha-tocopherol acetate (mg)	3·09	3·09	3·09	3·09	3·09	
Riboflavin (mg)	3·6	3·6	3·6	3·6	3·6	
Cyanocobalamin (μg)	7·5	7·5	7·5	7·5	7·5	
Prenylmenaquinone (mg)	1·2	1·2	1·2	1·2	1·2	
Niacin (mg)	18	18	18	18	18	
Pantothenic acid (mg)	4·95	4·95	4·95	4·95	4·95	
Butylated hydroxytoluene (mg)	9·9	9·9	9·9	9·9	9·9	
Manganese (mg)	49·5	49·5	49·5	49·5	49·5	
Iron (mg)	30	30	30	30	30	
Zinc (mg)	49·5	49·5	49·5	49·5	49·5	
Copper (mg)	4·95	4·95	4·95	4·95	4·95	
Iodine (mg)	0·3	0·3	0·3	0·3	0·3	
Selenium (mg)	0·15	0·15	0·15	0·15	0·15	
Fatty acid profile (g/kg fatty acids)						
Analysed						
Miristic	0·2	0·2	0·3	0·1	0·3	0
Palmitic	6·1	7·3	9·7	8·5	11·5	65
Palmitoleic	0·4	0·4	0·7	0·3	0·6	1
Stearic	1·7	2·3	3·7	2·9	4·5	29
Oleic	10·2	11·1	13·7	10·7	14·4	72
Linoleic	11·4	14·6	16·9	20	23·4	203
α-Linolenic	0·7	15	29·2	43·5	57·8	620
Arachidonic	0	0	0	0·1	0·1	3
Gadoleic	0	0	0	0·1	0·1	1
Calculated						
Linoleic:α-linolenic ratio	16·3	0·97	0·58	0·46	0·4	0·33

[1]Ayerza and Coates (1999).

were detected among treatments for either the white or the brown hens. Hen mortality was zero during the test.

No significant differences ($P>0·05$) in egg production were found among treatments for the brown hens throughout the trial. Egg production of the white hens given the 280 g/kg chia diet was significantly ($P<0·05$) lower than the hens given the control diet at d 30 and 58. White hens given the 210 g/kg chia diet had lower production at d 30 than those fed on the control diet. By d 90, that is at the end of the trial, egg production was not significantly different among treatments ($P>0·05$). The brown hens fed on chia produced significantly ($P<0·05$) heavier eggs throughout the trial than those given the control diet. Eggs produced by the white hens did not exhibit any significant

Table 2. *Hen weight, egg production, egg weight, and yolk weight and percentage from two strains of laying hens fed diets containing 4 levels of chia seeds and a control diet*

Parameter		White hens					Brown hens				
Day	Treatment (% chia)	Hen (g)	Eggs/hen/d	Egg (g)	Yolk (g)	Yolk (%)	Hen (g)	Eggs/hen/d	Egg (g)	Yolk (g)	Yolk (%)
0	0	1520	N/A	N/A	N/A	N/A	1870^{ab}	N/A	N/A	N/A	N/A
	7	1580^{a}	N/A	N/A	N/A	N/A	1780^{b}	N/A	N/A	N/A	N/A
	14	1570^{a}	N/A	N/A	N/A	N/A	1920^{a}	N/A	N/A	N/A	N/A
	21	1610^{a}	N/A	N/A	N/A	N/A	1950^{a}	N/A	N/A	N/A	N/A
	28	1600^{a}	N/A	N/A	N/A	N/A	1970^{a}	N/A	N/A	N/A	N/A
	cr[1]	122					120				
30	0	N/A	0·83^{a}	62·98^{a}	N/A	N/A	N/A	0·71^{a}	59·52^{b}	N/A	N/A
	7	N/A	0·82^{a}	60·05^{a}	N/A	N/A	N/A	0·66^{a}	64·38^{a}	N/A	N/A
	14	N/A	0·79^{ab}	62·54^{a}	N/A	N/A	N/A	0·66^{a}	64·17^{a}	N/A	N/A
	21	N/A	0·71^{b}	60·27^{a}	N/A	N/A	N/A	0·69^{a}	64·40^{a}	N/A	N/A
	28	N/A	0·72^{b}	60·26^{a}	N/A	N/A	N/A	0·68^{a}	64·35^{a}	N/A	N/A
	cr		0·10	3·89				0·12	3·44		
43	0	N/A	0·78^{a}	61·25^{a}	17·30^{a}	27·72^{a}	N/A	0·74^{a}	61·58^{b}	19·33^{a}	28·03^{a}
	7	N/A	0·74^{a}	60·05^{a}	16·32^{a}	26·53^{a}	N/A	0·66^{a}	64·99^{a}	18·13^{a}	27·65^{a}
	14	N/A	0·78^{a}	64·78^{a}	17·58^{a}	26·45^{a}	N/A	0·66^{a}	66·58^{a}	19·07^{a}	26·67^{a}
	21	N/A	0·72^{a}	61·06^{a}	17·70^{a}	26·88^{a}	N/A	0·65^{a}	65·04^{a}	19·45^{a}	28·40^{a}
	28	N/A	0·72^{a}	59·66^{a}	17·03^{a}	25·28^{a}	N/A	0·60^{a}	66·25^{a}	19·88^{a}	27·73^{a}
	cr		0·12	5·95	2·10	2·60		0·14	3·28	2·35	2·48
58	0	N/A	0·79^{a}	61·99^{a}	17·25^{a}	28·33^{a}	N/A	0·74^{a}	61·15^{c}	18·62^{ab}	28·06^{ab}
	7	N/A	0·70^{ab}	59·96^{a}	16·07^{a}	N/A	N/A	0·65^{a}	64·44^{b}	18·28 ^{ab}	N/A
	14	N/A	0·72^{ab}	60·86^{a}	17·38^{a}	27·17^{a}	N/A	0·62^{a}	65·63^{ab}	17·13^{b}	25·83^{c}
	21	N/A	0·71^{ab}	60·42^{a}	16·15^{a}	24·98^{a}	N/A	0·74^{a}	64·28^{b}	20·37^{a}	29·98^{a}
	28	N/A	0·61^{b}	57·70^{b}	16·73^{a}	27·75^{a}	N/A	0·61^{a}	67·05^{a}	19·18^{ab}	27·68^{bc}
	cr		0·17	3·66	1·97	2·31		0·15	2·46	2·21	2·22
72	0	N/A	0·67^{ab}	61·86^{a}	16·53^{a}	27·92^{a}	N/A	0·70^{a}	59·96^{c}	18·52^{a}	30·36^{a}
	7	N/A	0·58^{b}	56·43^{a}	16·27^{a}	27·75^{ab}	N/A	0·64^{a}	64·14^{b}	19·97^{a}	29·96^{ab}
	14	N/A	0·79^{a}	61·95^{a}	17·55^{a}	26·93^{ab}	N/A	0·62^{a}	66·50^{ab}	18·55^{a}	28·69^{ab}
	21	N/A	0·70^{ab}	59·19^{a}	16·57^{a}	24·98^{b}	N/A	0·73^{a}	64·95^{ab}	20·05^{a}	29·85^{ab}
	28	N/A	0·69^{ab}	58·31^{a}	17·80^{a}	27·30^{ab}	N/A	0·63^{a}	67·67^{a}	18·92^{a}	27·68^{bc}
	cr		0·19	6·18	2·42	2·87		0·17	3·10	1·76	2·63
90	0	1593^{a}	0·61^{a}	60·71^{a}	17·23^{a}	27·90^{a}	2000^{a}	0·69^{a}	58·35^{b}	17·72^{b}	28·80^{a}
	7	1558^{a}	0·69^{a}	55·72^{a}	15·22^{b}	25·58^{b}	1835^{a}	0·64^{a}	63·33^{a}	20·08^{a}	29·21^{a}
	14	1654^{a}	0·69^{a}	61·62^{a}	16·18^{ab}	26·27^{ab}	1976^{a}	0·62^{a}	66·14^{a}	18·23^{ab}	26·75^{a}
	21	1561^{a}	0·53^{a}	61·12^{a}	16·50^{ab}	26·53^{ab}	1884^{a}	0·65^{a}	65·04^{a}	19·35^{ab}	28·35^{a}
	28	1628^{a}	0·68^{a}	58·57^{a}	16·08^{ab}	28·12^{a}	1876^{a}	0·62^{a}	66·66^{a}	19·08^{ab}	26·22^{a}
	cr	127	0·22	7·21	1·43	2·16	169	0·25	4·05	2·36	3·16

[1]Critical range for mean separation.
Means within a grouping lacking a common superscript differ (P<0·05) according to Duncan's multiple range test.
N/A = not applicable or not measured.

differences (P>0·05) in weight between the control and the chia diets, except for the 280 g/kg chia diet on d 58, which produced significantly lighter (P<0·05) eggs.

Yolk weights for the white hens fed on chia were not significantly different (P>0·05) from those produced by the hens given the control diet up until d 90. On that date, hens given the 70 g/kg chia diet produced eggs with yolks significantly lighter (P<0·05) than the control (Table 2). Yolk weight for the brown hens was not significantly different (P>0·05) throughout the experiment except also on d 90. In this case, however, hens that had been fed on the 70 g/kg chia diet produced egg yolks significantly heavier (P<0·05) than those given the control diet (Table 2). Egg yolk as a percentage of egg weight for the white hens was significantly lower (P<0·05) at d 72 and at d 90, for 210 and 70 g/kg chia diets, respectively, than with the control diet (Table 2). In the brown hens, yolk percentage was significantly (P<0·05) lower on d 58 for the hens given the 140 g/kg chia diet, and on d 72 for the hens given the 280 g/kg chia diet, than those fed the control diet.

Results between strains

Egg production was significantly (P<0·05) lower with the brown hens given the control diet and the 70 g/kg chia diet at d 30, and at d 43 and 72 when fed on the 140 g/kg chia diet. Egg weight was significantly different (P<0·05) between the two strains for the hens given chia in 16 of the 20 cases, with the brown hens producing heavier eggs in each instance. With the control diet, no significant differences (P> 0·05) in egg weight between strains was found.

Generally, yolk weight and yolk weight as a percentage exhibited similar behaviour between the chia and the control diets. Yolks from the brown hens were heavier, or represented a greater percentage of total egg weight, than yolks from the white hens in all cases but with the 140 g/kg chia diet on d 58. The results, however, were not always significantly different ($P>0{\cdot}05$) between strains. With yolk weight, significant differences were generally detected as the trial progressed. For yolk percentage, significant differences were detected only with the 70 g/kg chia diet on d 90, and with the 210 g/kg chia diet on d 58, 72 and 90.

Sensory evaluations

No significant differences ($P>0{\cdot}05$) in taste preference or flavour for either strain were detected among eggs produced by hens fed on the control, 70, 140 and 280 g/kg chia diets. Taste preference ranged from 3·60 to 3·80 for the white eggs, and from 3·63 to 4·38 for the brown eggs. Flavour ratings ranged from 2·50 to 3·00 for the white eggs, and from 2·25 to 3·25 for the brown eggs. No significant difference in sensory characteristics between strains was detected.

DISCUSSION

Hen weight

The results of the current study support earlier work by Ayerza and Coates (1999), which indicated that body weight was not negatively affected when hens were fed on chia. This result is unlike the findings of others when feeding flax to hens. Hens given flax at 50 and 150 g/kg of the diet had lower feed intake and lighter body weight than those given a control diet (Scheideler and Froning, 1996). Several papers suggest that the negative effect of flax seed in poultry rations arises because of the antinutritional cyanogenic glucosides and vitamin B6 antagonist compounds in flax (Kung and Kummerow, 1950; Homer and Schaible, 1980; Bell, 1989; Bhatty, 1993; Bond *et al.*, 1997).

Egg production

Egg production by the brown hens was not affected by the chia, nor was it in 88% of cases for the white hens (Table 2). The reason for the decrease in production with the white hens fed the 210 g/kg chia diet at d 30, and the 280 g/kg chia diet at d 30 and 58 is not clear. Because the decreases were observed only with the two highest concentrations of chia, it may suggest that an upper limit exists for chia in the white hens' diet, or that they adapt more slowly to chia than do the brown hens. The data show that, for the last two periods, egg production for the white hens given chia was not significantly different from those fed on the control diet.

Similar findings to those for the brown hens given chia (that is, egg production was unaffected) were reported for two commercial SCWL genotypes of 24-week-old hens given fish meal at 40, 80 and 120 g/kg of the diet (Nash *et al.*, 1995), and for hens given flax seed at 100 and 200 g/kg of the diet (Caston *et al.*, 1994). Other experiments, however, have shown different results. When 50 g/kg flax seed and 15 g/kg menhaden fish oil diets were fed to 22-week-old SCWL laying hens, no significant differences ($P>0{\cdot}05$) in egg production were found compared with hens fed a control diet. However, when hens were given a 150 g/kg flax diet, production declined (Ayamond and van Elswyk, 1995).

The results described in this paper are different from those reported by Ayerza and Coates (1999) for hens given a 300 g/kg chia diet. These authors found the chia to have a negative effect on egg production, throughout the trial. The decrease in production in the previous (1999) trial may have been due to the highly unbalanced diet that was used, with chia seed simply replacing a portion of the control diet. Ayerza and Coates (1999) also used a different breed of hens, and this also may have influenced the results.

The effect of diet on egg production was small in both strains, with a significant effect found on only three days, or 15% of the total days. Because one instance was with the hens fed on the 70 g/kg chia diet, and the other two for the hens on the 140 g/kg chia diet, there did not appear to be a chia × strain interaction although this was not statistically determined. On the control diet the white hens were more productive than the brown hens on the first three dates, but significantly so only for the first date. At the lowest chia content the white hens exhibited the same behaviour as with the control diet. At the highest chia levels (210 and 280 g/kg) the differences were similar, but none were significant. These data could be interpreted as indicating that the white hens' production tended to decrease at the higher chia levels, but that the brown hens' production did not.

Egg weight

Egg weight is an important economic trait because it defines market grade. In Argentina and the USA an increment of 1 g in egg weight can improve the grade, and hence income from eggs, by 5 and 4%, respectively (Shalev and Pasternak, 1993; D. Fernandez, 1998, personal communication).

Three studies with flax seed (Caston and Lesson, 1990; Caston *et al.*, 1994; Scheideler and Froning, 1996) reported no significant difference in egg weight, when feeding up to 200 g/kg flax. However, Scheideler and Froning (1996) found a consistent effect with fish oil, as well as whole and ground flax seed, in that they decreased egg weight by 1·5, 5 and 15%, respectively. Herber and van Elswyk (1996) reported a decrease in egg weight with hens given 15 g/kg menhaden fish oil and 48 g/kg marine algae at 24 weeks of age, but not at 56 weeks of age. They suggested that a diet × age interaction exists, and that differences in reproductive maturity may have led to the differing effects of the dietary omega-3 fatty acids on egg weight. When feeding Isa Brown hens, Ayerza and Coates (1999) found no change in egg weight with a 300 g/kg chia diet, compared with a control diet.

In the current study, differences in egg weights were found. The white hens given the 280 g/kg chia diet produced significantly lighter eggs at d 58 than those fed on the control diet, and this coincided with a decrease in egg production. A reduction in both parameters is a strong indication that the 280 g/kg chia diet was inadequate for the white hens. On the other hand, chia significantly increased egg weight with the brown hens. Eggs produced by the brown hens fed on chia averaged more than 64 g, white eggs from hens fed on the control diet averaged only 62 g. The eggs produced by the hens fed on chia would receive an 'extra large' grade (>62 g), the highest grade in the Argentina egg market (SENASA, 1988). Meanwhile eggs from the control diet would receive only a 'large' grade (54 to 62 g). All of the eggs produced by the white hens would receive a grade of large. The increase in egg weight found with the brown hens was probably due to the higher lipid content of the chia diets, compared with the control diet. This is supported by the statement cited in *Nutrient Requirements of Poultry* (National Research Council, 1994) that says providing dietary fat decreases the need for hepatic fatty acid synthesis and generally increases yolk formation and egg weight.

Genetic influences on egg weight have been reported (Washburn and Marks, 1983; Poggenpoel and Duckitt, 1988), and could explain the difference in chia assimilation between the brown and the white hens. Because egg weight of brown hens increased, without an increase in feed intake or a decrease in egg number, adding chia in quantities up to 280 g/kg of the brown hens' diet is possible. Increased egg size without increased feed consumption provides an opportunity for commercial egg producers to improve feed efficiency.

Egg weights were significantly greater for the brown hens fed on chia, on 75% of the dates, than for the white hens. No differences were detected with the control diet. Thus, the egg weight difference found between strains could be associated with a chia × strain interaction, although this was not statistically determined. Breed effects on feed consumption and egg weight have been reported (Scheideler *et al.*, 1998*b*). Such an interaction may have implications in directing chia feeding programmes with commercial flocks. Further investigations with chia should include feeding of white and brown hens over a wider range of ages to determine if a diet × age interaction exists.

Eggs with smaller yolks, which contain significantly less cholesterol than eggs with larger yolks, could be an important factor when promoting the consumption of eggs (Shafey and Cham, 1994). Yolk weight at d 90 in the white hens given chia, and yolk weight as percentage of egg weight at d 72 and 90 with the 70 and 210 g/kg chia diets, were less than those of the brown hens. Caston and Leeson (1990), when feeding flax at 100, 200 and 300 g/kg of the ration, did not show significantly lower yolk weight or yolk weight compared with the control. In their case, however, the trial lasted only 30 d. Other trials with longer feeding periods reported variations in egg yolk as a percentage of egg weight. Caston *et al.* (1994), in a 336 d trial, found a significant difference by the 5th 28-d period in yolk percentage between hens given 100 and 200 g/kg flax diets, and those fed a control diet. Scheideler and Froning (1996), in a 56-d trial, reported a significant difference in yolk percentage between hens given 15 g/kg fish oil, and 50, 100 and 150 g/kg flax diets, and hens given a control diet. In this case the hens were fed on the experimental diets for 140 and 49 d, respectively, prior to the start of the trial. The initial feeding period effectively increased the length of each trial. Yolks from hens given the fish oil and the flax diets in both of these trials were smaller on a percentage basis, than those from hens receiving the control diet.

Sensory evaluation

Although no differences in taste preference or flavour were detected, it should be noted that off-flavours have been found to be most detectable in scrambled eggs (van Elswyk *et al.*, 1992, 1995). If more rigorous tests were done, different findings might arise. Eggs from hens fed on flax seed or fish products (meal and oil) have scored significantly lower in preference evaluations than those fed a control diet (Adam *et al.*, 1989; Jiang *et al.*, 1992; van Elswyk *et al.*, 1992, 1995; Caston *et al.*, 1994). Food off-flavours are often associated

with lipid oxidation (Frankel, 1984). Inclusion of tocopherols as an antioxidant in flax or fish oil diets resulted in a significant improvement in oxidative stability of eggs, compared with those without tocopherols (Cherian *et al.*, 1996). Analyses of chia seed have indicated a potent antioxidant activity (Taga *et al.*, 1984). It is suspected that the lack of off-flavour in the eggs produced by the chia-fed hens may be a result of this antioxidant activity.

A recent report by Leeson *et al.* (1998) showed that adding vitamin E to a hen's diet containing 100 or 200 g/kg flax, still produced eggs with perceptible off-flavour. The effect was accentuated at high inclusions of vitamin E and could be connected with a pro-oxidant action of vitamin E, rather than an antioxidant effect at very high concentrations. Marshall *et al.* (1994*b*) reported that lipid oxidation in eggs from hens given 15 g/kg menhaden oil did not contribute to detectable off-flavours. The authors advanced the theory that the correlation between the level of oxidation products, as indicated by thiobarbituric acid (TBA) test, and sensory quality of cooked whole eggs may not be as high as was previously thought. This could indicate that egg off-flavours arise because of other interactions between diet and hen physiology, and are not necessarily related to oxidation.

A study conducted in 5 US cities showed that consumers were willing to purchase omega-3 enriched eggs to improve the omega-3 fatty acid level in their diets. However, consumers had some concerns about egg off-flavour (Scheideler *et al.*, 1997). As chia has been shown to increase the omega-3 content of eggs (Ayerza and Coates, 2000), as have flax seed and fish products, but without imparting off-flavours, this would indicate a strong advantage for chia over flax seed and fish products as a laying hen feed.

In summary, this study showed that up to 280 g/kg chia seed can be fed to brown laying hens with no adverse effects on egg production, and with increased egg weights. The white hens were superior in terms of egg production with the 70 g/kg chia diet; however, they tended to have lower egg production when fed on diets containing more than 140 g/kg chia. Additional work also needs to be done to determine if a genotype × chia diet relationship exists, before one strain or breed could be endorsed as being superior in utilising chia. Hen weight was not affected by the chia, nor was egg flavour.

The results of this study show that chia seed could be an alternative to flax seed and marine sources to produce eggs more acceptable to the health conscious public. It could also help to reverse the declining per capita consumption of eggs which has taken place in recent years.

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