Effects on egg quality traits of genotype and diets with mussel meal or wheat-distillers dried grains with solubles

H. Wall,*[1] L. Jönsson,* and L. Johansson†

*Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, SE-753 23 Uppsala, Sweden; and †Department of Food Science, Swedish University of Agricultural Sciences, PO Box 7051, SE-750 07 Uppsala, Sweden

ABSTRACT The aim of the study was to evaluate effects on exterior and interior egg quality and sensory characteristics of eggs from hens fed diets with admixtures of 3.5 or 7.0% of mussel meal or 20% wheat-distillers dried grains with solubles (DDGS). The mussel meal diets followed organic standards, whereas the DDGS diet was formulated for hens in conventional production. Standard diets, one organic and one conventional from a Swedish feed manufacturer, were included for comparison. The study used 164 Hy-Line White W-98 and 164 Hy-Line Brown layers housed in small-group furnished cages. Egg flavor or odor was not affected by genotype. Egg flavor intensity was stronger in eggs from hens fed either of the mussel diets or the standard organic diet compared with the conventional diet. There were no differences between any of the diets in egg odor intensity, off-flavor, or off-odor. The mussel diets and the standard organic diet gave stronger yolk pigmentation than the conventional and DDGS diet, respectively. Manure DM was lower with the admixture of 7.0% mussel meal than 3.5%. There was a tendency ($P < 0.10$) toward a difference between diets in dirty eggs, and the percentage was highest with 7.0% mussel meal. Diet or genotype had no effect on egg weight, albumen height, shell deformation, shell breaking strength, or proportion of cracked eggs. Genotype differences were found in weight percentage of albumen, yolk, and shell and in the presence of blood and meat spots and in percentage of dirty eggs. In conclusion, the majority of egg quality traits were unaffected by the diets studied. With the admixture of DDGS used in the present study, the characteristics of eggs were similar to those of eggs produced on the conventional standard diet. There was no indication of impaired egg odor or flavor with the used fractions of DDGS or mussel meal.

Key words: egg quality, sensory characteristic, mussel meal, distillers dried grain with solubles, layer

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INTRODUCTION

There is a growing interest in finding alternative protein feedstuffs for laying hens in Sweden as well as in other countries in Europe. The need for new sources of high-quality protein is increasing especially in the organic egg production as the regulation concerning the feed is becoming stricter. At present, the prohibition on use of synthetic amino acids (**AA**), genetically modified organisms, or products derived from and products processed using chemical solvents (EC, 2007) makes it more difficult to compose diets fulfilling the needs of organic laying hens. Furthermore, in 2012, feed used in organic animal production must be fully organic [i.e., it will no longer be allowed to use a smaller portion of nonorganic feed ingredients such as potato protein or maize (*Zea mays*) gluten meal generated from conventionally produced crops].

Compared with other species, poultry in general have a considerably higher need for the sulfuric AA methionine. Fish meal provides a very good source of methionine and is currently used in organic diets for layers. However, using ocean fish stocks to feed animals can be questioned because there is a shortage of fish in the seas and it could be argued that the fish should be kept for human consumption. Another potential marine protein source is blue mussels (*Mytilus edulis*). Recent studies have shown that meal produced from dried meat of mussels (i.e., mussel meal) is an excellent source of protein and from a nutritional aspect a possible substitute for fish meal in diets for laying hens (Jönsson and Elwinger, 2009). In addition, growing mussels provide ecologic benefits because mussels use considerable

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[1]Corresponding author: Helena.Wall@huv.slu.se

amounts of phosphorous and nitrogen that leak out to the oceans from agriculture (Lindahl et al., 2005).

The growing interest in using ethanol as a substitute for petroleum generates an increased production also of the by-product distillers dried grains with solubles (**DDGS**). The fermentation process results in approximately equal portions of ethanol, carbon dioxide, and DDGS (Lumpkins et al., 2005) and the disposal of the by-product may become a problem. In a review, Świątkiewicz and Koreleski (2008) conclude that DDGS can replace soybean meal and cereals in diets for laying hens. Distillers dried grains with solubles are rich in proteins but their content of sulfuric AA is not high enough to fill hens' need of essential AA on their own. However, in combination with synthetic AA, a considerable fraction of DDGS can still be included in diets for conventional hens. Combined with feedstuffs high in methionine, DDGS may also have a nutritional value for laying hens in organic egg production.

Several studies have shown that feeding layers with fish meal or fish oil may reduce the sensory quality of eggs (Koehler and Bearse, 1975; Van Elswyk et al., 1995). Also, small amounts of high-quality deodorized fish oil (i.e., fish oil that has been treated to eliminate the problem with fishy flavor in the final food product) have resulted in impaired sensory quality of eggs (Gonzalez-Esquerra and Leeson, 2000). Because mussel meal is a potential future protein source for organic laying hens and DDGS may become a common ingredient in laying hen diets, evaluating possible effects on egg quality and sensory traits is important. The purpose of the present experiment was to study possible effects on exterior and interior egg quality and sensory characteristics of eggs from hens fed diets with 20% wheat-DDGS or different admixtures (3.5 and 7.0%) of mussel meal. As comparison, 2 standard diets manufactured by a Swedish feed company were also included in the experiment. All diets were evaluated on 2 commercial laying hen genotypes during a full production period.

MATERIALS AND METHODS

Birds and Housing

The study was composed a total of 328 hens, of which half were Hy-Line W-98 (**HW**) and half were Hy-Line Brown (**HB**). The pullets were reared in conventional rearing cages for laying hens and in accordance with prohibition in Sweden, without beak-trimming. At 16 wk of age, the birds were transferred to the experimental building, where they were housed in furnished 8-hen or 10-hen cages receiving 10 h of light per day. The light was successively increased to 16 h per day at 31 wk of age. The study was carried out from June 2006 until June 2007, comprising the time from 20 to 72 wk of age.

The 8-hen cage measured 96 × 50 cm (width × depth) and was 45 cm high at the rear, nest and litter box excluded. A nest box, 25 cm wide and 50 cm deep, lined with artificial turf was positioned at one end of the cage. On top of the nest was a litter box. The 10-hen cage was of similar design but had 2 nest boxes and a larger litter box. For a more detailed description of cage design and management routines, see Wall and Tauson (2007). All cages fulfilled the Swedish Animal Welfare Directives of a minimum of 600 cm^2 cage floor area per hen, with areas of nest and litter box excluded.

Diets and Feeding

During rearing, the pullets were fed a conventional grower crumbled diet. From 20 wk of age, each group of hens was given 1 of 5 diets (Table 1). The diets used were 3 experimental diets containing 3.5 or 7.0% mussel meal or 20% wheat-DDGS, a standard organic diet, or a standard diet for conventional egg production. The standard diets were bought from a Swedish feed manufacturer and were included as comparison. Each group of 8 or 10 hens represented 1 experimental unit. The DDGS diet was fed to 2 groups of each genotype housed in 10-hen cages generating 2 replicates per genotype. The other 4 diets were distributed to hens in 8-hen cages, resulting in 4 or 5 replicates per combination of genotype and feed. All diets were pelleted and crumbled. Feed was supplied daily by hand and was available ad libitum. The organically approved antioxidant Vitalox (Helm, Hamburg, Germany) was added when the mussel meal was prepared.

Dry matter, CP, and ash were analyzed at each feed delivery (Table 2). Birds fed the conventional standard diet followed a phase feeding program recommended by the feed manufacturer and therefore changed feed twice during the production period. The composition of the standard diets, conventional and organic, varied between feed batches (Table 1), whereas the composition of the experimental diets with mussel meal or DDGS was fixed.

Sensory Evaluation

A descriptive test, conventional profiling (International Organisation for Standardisation, 1985), was carried out by a trained 6-member sensory panel (International Organisation for Standardisation, 1993) when hens were 56 wk old. The sensory analysis was preceded by 3 training sessions, of 2 h each, in which eggs were presented from the 2 laying hen genotypes fed the 5 different diets. During the first training session, egg samples were presented to the panel to generate a set of odor and flavor attributes. The sensory training was performed in accordance with ISO 6564 (International Organisation for Standardisation, 1985). The panel members were in agreement on how the eggs should be prepared, the samples be served, and what attributes to assess. Eggs were prepared 7 at a time in an egg boiler for 15 min and an egg cutter was used to di-

Table 1. Composition of diets used[1]

Ingredient (%)	Diet: Mussel 3.5%[2] (20 to 72 wk)	Mussel 7.0%[2] (20 to 72 wk)	DDGS[3] (20 to 72 wk)	Standard organic[4] (20 to 72 wk)	Conventional[3] (20 to 26 wk)	Conventional[5] (27 to 50 wk)	Conventional[6] (50 to 72 wk)
Wheat	39.2	35.9	44.3	60.5 ± 1.1	59.3	60.0 ± 0.29	60.2 ± 0.22
Peas	20.0	20.0	11.1	—	—	1.7 ± 1.5	8.5 ± 1.5
Oats	14.0	10.8	10.0	8.0	5.0	5.0	5.0
Wheat-DDGS	—	—	20.0	—	—	—	—
Maize gluten meal	6.4	—	0.75	9.7 ± 0.5	—	—	—
Mussel meal	3.5	7.0	—	—	—	—	—
Fish meal	—	—	—	2.2 ± 0.6	—	—	—
Green grass meal	—	3.5	0.70	0.02	0.60	—	—
Malt sprouts	—	—	—	—	5.0	5.0	0.38 ± 0.48
Potato protein	2.6	—	—	—	—	—	—
Soy press cake	1.6	10.0	—	8.3 ± 1.1	—	—	—
Soy meal	—	—	—	—	16.0	13.3 ± 0.6	11.8 ± 1.7
Soy oil	1.5	1.5	—	—	—	—	—
Fatty acids	—	—	2.3	—	2.8	2.4	2.0 ± 0.2
Ingredients of minor contribution[7]	—	—	—	0.18 ± 0.15	0.60	0.67 ± 1.2	—
Calcium carbonate	9.7	9.8	9.0	9.8 ± 0.2	9.6	10.0	10.5 ± 0.06
Monocalcium phosphate	0.90	0.93	0.73	0.73 ± 0.07	0.70	0.57 ± 0.06	0.41 ± 0.02
NaCl	0.34	0.30	0.31	0.31 ± 0.02	0.37	0.37	0.35
Pigment premix (paprika, *Tagetes*)	—	—	0.12	0.10	0.10	0.30	0.30
Other feed additives[8]	0.25	0.25	0.73	0.25	0.44	0.46	0.43
Sum	100	100	100	100	100	100	100

[1]Mussel 3.5%, mussel 7.0%, and distillers dried grains with solubles (DDGS) diets were experimental diets. Conventional (CONV) diets constituted a phase feeding program for conventional hens, implying a change of the nutritional composition of the diet twice during the production cycle. The composition of the diets in the conventional phase feeding program and the standard organic diet varied between feed batches, and content in the table is, therefore, presented as mean value ± SD.

[2]Seven batches of feed.

[3]One batch of feed.

[4]Six batches of feed.

[5]Three batches of feed.

[6]Four batches of feed.

[7]Minor fractions (<0.70 g/kg of feed) of barley, wheat bran, or wheat middlings.

[8]Vitamin premix (all diets), synthetic amino acids (DDGS and CONV diets), and phytase enzyme (CONV diets).

vide each hard-boiled egg into 6 segments. Thereby the same egg was assessed by all 6 panel members. Only the egg yolks were assessed. Each sample was served in a plastic container covered with a lid. Each box was coded with 3-digit random numbers.

The evaluation was carried out in a room at separate tables and results were registered on protocols using a continuous uncategorized line scale labeled low intensity at 0 and high intensity at 10 at the ends. The panel members were told to take a sniff of the sample in the box for evaluation of intensities of odor and off-odor. Thereafter, the sample was tasted for evaluation of intensities of flavor and off-flavor. If an off-odor or off-flavor was detected, the assessors were asked to write down the characteristics of the attributes (e.g., sulfuric, metallic, or fishy). The assessors were instructed to rinse their mouths with lukewarm tap water and eat neutral wafers between samples. The test was conducted on 2 consecutive days. During a period of 2 h, 4 sets of 5 egg segments, from the different treatments, were randomly served to the panel members. In the evaluation, 1 egg from each of the 8-hen cages (36 cages) and 2 eggs from each of the 10-hen cages (4 cages) were used.

Exterior and Interior Egg Quality Traits and Excreta DM Content

A small version of a commercial egg-candling machine was used to detect cracked and dirty eggs. All eggs collected during 5 consecutive days were candled on 5 occasions (at 33, 40, 51, 64, and 70 wk of age). Because the hens fed the DDGS diet were not housed in cages identical to the cages housing the other hens in the study, the DDGS diet was not included in the comparison of exterior egg quality.

At 55 wk of age, 5 eggs from each replicate in the 8-hen cages and 10 eggs from the 10-hen cages were analyzed for egg weight, albumen weight, albumen height, albumen DM (dried at 105°C), egg yolk pigmentation, weight of eggshell, shell deformation, shell breaking strength, and blood and meat spots. The Canadian Egg Shell Tester (Otal Precision Company Ltd., Ottawa, Ontario, Canada) was used for measurements of shell breaking strength and shell deformation. Shell deformation was calculated from the average value of measurements on 3 different spots across the equator, after a load of 1,000 g was applied on the egg. Eggs for which the SD of the repeated measurements of shell deformation exceeded 15×10^{-3}mm were excluded (14 eggs out of 220) from the analyses of interior egg quality. To measure eggshell weight, the broken eggshells with membranes were rinsed in distilled water and thereafter dried at 65°C for 14 h before weighing. Egg yolk pigmentation was analyzed with visual comparisons using the La Roche color fan with a scale from 1 to 15. Dry matter content in fresh excreta samples collected from the manure belts was analyzed at 60 wk of age.

Statistical Methods

Data were analyzed as mixed linear models (Littell et al., 2006). The MIXED procedure of the SAS Institute (2004) package was used for the analyses. The interior egg quality traits and manure DM were analyzed with genotype, diet, and genotype × diet interaction as fixed effects and with genotype × diet × replicate as random effect in the model. Exterior egg quality was analyzed as above but with age of birds (33, 40, 51, 64, and 70 wk) and interaction between bird age, genotype, and feed included in the model with adjustment for repeated measurements.

In the analyses of the sensory evaluation, the models included the fixed effects of set (i.e., set of 5 samples served at the same time), genotype, diet, and the set × diet and genotype × diet interactions. The random effects were set × genotype, set × genotype × diet, and panel assessor.

To analyze individual differences, Fisher's protected least significant difference test and Bonferroni correction for multiple comparison were used. Because interior egg quality traits are probably not to be affected by details in the hens' housing environment, cage model was not included in the statistical analyses of those traits.

RESULTS

Results of egg quality and sensory traits are presented in Table 3. Egg flavor intensity was stronger in eggs from hens fed the 2 mussel meal diets and the standard organic diet compared with the conventional diet. There were no differences between any of the diets in egg odor intensity, off-flavor, or off-odor. None of the sensory traits were affected by genotype.

Egg weight was not affected by laying hen diet or genotype. The 3.5% mussel diet generated eggs with a higher albumen weight percentage than the conventional diet. The weight percentage of egg yolk was higher from hens fed the conventional diet than from those fed the 2 mussel meal diets. Eggs laid by HB hens had higher albumen weight percentage and lower yolk weight percentage compared with eggs from HW hens. Neither albumen height or albumen Haugh unit was affected by genotype or diet. There was a tendency ($P < 0.10$) pointing at an effect of diet on albumen DM.

Egg yolk pigmentation was stronger in eggs from hens fed the standard organic diet and the 2 mussel

Table 2. Calculated and analyzed nutrient content in diets used[1]

	Diet						
Nutrient[2] (g/kg of feed)	Mussel 3.5%[3] (20 to 72 wk)	Mussel 7.0%[3] (20 to 72 wk)	DDGS[4] (20 to 72 wk)	Standard organic[5] (20 to 72 wk)	Conventional[4] (20 to 26 wk)	Conventional[6] (27 to 50 wk)	Conventional[7] (50 to 72 wk)
ME[8] (kcal/kg)	2,715	2,595	2,629	2,722	2,688	2,667	2,640
CP	185	189	160	188	165	155	150
CP[9]	190 ± 10	193 ± 7	166	194 ± 17	164	158 ± 8	155 ± 4
Lysine	9.2	11.3	7.7	7.0	7.8	7.3	7.1
Methionine	3.3	3.0	4.1	3.6	4.0	4.0	3.7
Methionine + cysteine	6.9	6.3	7.4	—	—	—	—
Fat	43	51	53	36	49	44	40
Crude fiber	37	43	46	34	39	39	36
Calcium	37	37	35	37	38	39	41
Phosphate	5.2	5.6	5.5	5.0	5.0	4.6	5.8
Sodium	1.6	1.5	1.5	1.6	1.6	1.6	1.5
Xanthophyll (mg/kg)	—	—	7.2	16.1	5.4	6.0	8.0
Ash[9]	136 ± 29	136 ± 23	116.7	136 ± 9.5	135.3	142 ± 6.6	165.8 ± 4.2
DM[9] (%)	89.7 ± 1.3	90.4 ± 1.4	90.6	90.1 ± 1.1	903	89.8 ± 1.01	89.8 ± 0.7

[1]Mussel 3.5%, mussel 7.0%, and distillers dried grains with solubles (DDGS) diets were experimental diets and standard diets for conventional and organic production, respectively. Conventional diets constituted a phase feeding program, and therefore, feed composition and nutrient content were changed twice during the production cycle.

[2]Calculated values. Vitamin premix provided the following (per kg of feed): vitamin A, 10,000 IU; vitamin D, 2,500 IU; choline, 1,040 mg; copper, 6.5 mg; and selenium, 0.3 mg.

[3]Seven batches of feed.

[4]One batch of feed.

[5]Six batches of feed.

[6]Three batches of feed.

[7]Four batches of feed.

[8]Energy calculated according to the World's Poultry Science Association method.

[9]Analyzed values.

meal diets compared with that of eggs from hens fed the conventional or the DDGS feed. Yolk pigmentation did not differ between the genotypes. Eggs from HW hens had a lower shell weight percentage, but there was no difference in eggshell deformation or shell breaking strength. Neither eggshell weight, deformation, or breaking strength was affected by diet.

The proportion of cracked eggs was not affected by diet or genotype. The highest percentage of dirty eggs was found with the 7.0% mussel meal diet, but there was only a tendency ($P < 0.10$) of effect of diet on dirty eggs. The percentage of dirty eggs was higher for HW hens than for LB hens ($P < 0.001$). Manure DM was lower with the 7.0% mussel diet as compared with the 3.5% mussel diet. Manure DM was not affected by genotype.

Meat spots (not shown in the tables) were detected in on average 6% of analyzed eggs, but there were no significant differences between genotypes or diets. The share of eggs with blood spots was significantly larger in eggs from HB (27%) compared with those from HW (0%). Blood spots were not affected by diet.

DISCUSSION

The difference found in egg flavor intensity between some of the diets only reflects how intense the egg taste was perceived by the panel and was not proof of whether an egg was perceived as more or less pleasant. A more important result of the sensory evaluation was the lack of differences between the diets in off-flavor and off-aroma, indicating that no negative effects of mussel meal or DDGS on the flavor and aroma of eggs were found at the levels used in this study.

In the present study, eggs were stored for 3 d before the sensory evaluation was conducted and possible effects of storage were not evaluated. In recent studies on eggs from quails fed diets with fish residue chemical silage (Seibel et al., 2007) or layers fed diets with shrimp head meal (Carranco-Jáuregui et al., 2006), only minor effects or no effect at all were found from storage on the sensory attributes of eggs. On the other hand, in an earlier study in which hens were fed diets with 5 or 10% fish meal rations from different sources (Koehler and Bearse, 1975), storage of eggs for 4 wk intensified undesired flavor characteristics. However, in the present study, the panel members did not register many cases of off-odors or off-flavors. Evaluating possible effects of storage may probably have been more interesting if undesired flavor or odor had been frequently found.

Reduced egg weight has been reported in several studies conducted on hens fed fish products such as fish oil (Elwinger and Inborr, 1999; Gonzalez-Esquerra and Leeson, 2000). Such changes in egg weight are possibly associated with dietary n-3 and alterations in birds' lipid metabolism (Van Elswyk et al., 1992). In the present study, egg weight was not significantly affected by genotype or diet composition, but the yolk weight percentage was lower in eggs from hens fed mussel meal diets. In agreement with the results in the present study, Marshall et al. (1994) showed that inclusion of 1.5% fish oil reduced the egg yolk weight but did not alter

Table 3. Interior and exterior egg quality traits and sensory characteristics of eggs from 2 commercial genotypes of laying hens fed 5 different diets

	Diet[1]					Genotype[2]			Statistical significance		
Trait	Mussel diet 3.5% (n = 9)	Mussel diet 7.0% (n = 9)	DDGS diet (n = 4)	Standard organic diet (n = 9)	Conventional diet (n = 9)	HW (n = 20)	HB (n = 20)	SEM	Diet	Genotype	Diet × genotype
Egg flavor intensity[3]	6.37[a]	6.54[a]	6.11[ab]	6.59[a]	5.60[b]	6.38	6.12	0.23	0.001	0.24	0.90
Egg odor intensity[3]	5.49	5.39	5.08	5.40	5.06	5.30	5.27	0.26	0.13	0.85	0.80
Off-flavor[3]	0.70	0.88	0.61	0.70	0.31	0.66	0.62	0.30	0.20	0.76	0.38
Off-odor[3]	0.52	0.44	0.10	0.40	0.10	0.35	0.28	0.21	0.34	0.66	0.91
Egg weight (g)	71.0	69.6	69.3	67.9	68.8	69.6	69.1	0.602	0.15	0.53	0.93
Albumen weight (%)	60.3[a]	60.1[ab]	59.9[ab]	58.4[ab]	58.0[b]	58.7	60.0	0.355	0.01	0.01	0.87
Yolk weight (%)	30.8[b]	30.9[b]	31.3[ab]	32.2[ab]	33.0[a]	32.5	30.8	0.35	0.05	0.01	0.82
Albumen height (mm)	8.0	8.3	8.4	8.5	8.7	8.3	8.4	0.16	0.26	0.74	0.51
Haugh unit	85.7	87.9	88.7	89.5	90.6	88.1	88.9	0.96	0.15	0.59	0.59
Albumen DM (%)	12.3	12.3	12.8	12.0	12.4	12.4	12.4	0.100	0.06	0.86	0.57
Yolk color[4]	10.7[ab]	11.3[a]	8.00[c]	10.3[b]	7.65[c]	9.71	9.44	0.117	0.001	0.12	0.99
Shell weight (%)	8.84	9.04	8.79	9.31	9.01	8.84	9.16	0.091	0.10	0.05	0.97
Shell deformation (10^{-3} mm)	64.8	64.2	63.6	61.3	64.3	64.7	62.6	1.09	0.53	0.18	0.45
Breaking strength (g)	4,098	4,126	3,946	4,170	3,977	4,006	4,121	61.37	0.44	0.19	0.11
Cracked eggs (%)	2.5	2.0	—	0.96	2.6	2.2	1.8	0.41	0.23	0.39	0.30
Dirty eggs (%)	7.7	13.8	—	7.8	10.2	14.5	5.2	1.2	0.06	0.001	0.14
Manure DM (%)	26.2[a]	23.1[b]	23.6[ab]	25.6[ab]	24.3[ab]	25.1	24.0	0.49	0.05	0.13	0.65

[a–c]Values within rows with different superscripts are significantly different (at least $P \leq 0.05$).

[1]DDGS = distillers dried grains with solubles.

[2]HW = Hy-Line W-98; HB = Hy-Line Brown.

[3]Range: low intensity = 0, high intensity = 10.

[4]Score from 1 to 15; greater score = stronger yolk color.

the egg weight. However, the feeds used in the present study differed not only in their content of mussel meal, and it cannot be excluded that also other differences in the diet compositions affected egg yolk weight.

The higher percentage of albumen weight and lower percentage of yolk of eggs from the brown HB hens in comparison with those of eggs from the white HW hens agree with earlier studies on eggs from commercial genotypes of white and brown hens (Abrahamsson et al., 1996; Scott and Silversides, 2000; Silversides and Scott, 2001). Scott and Silversides (2000) concluded that the lower percentage of egg yolk in eggs from brown genotypes may be a consequence of a high selection pressure for improved egg production in brown layers, whereas commercial white genotypes have had a high egg production for many years and more emphasis can therefore be given to secondary traits such as egg yolk weight.

The height of the albumen is generally higher in eggs from white genotypes compared with brown (Abrahamsson et al., 1996; Scott and Silversides, 2000; Silversides and Scott, 2001). However, in the present study, no differences between genotypes were found in albumen height or in Haugh unit. Converting albumen heights into Haugh units is a common adjustment for differences in egg weight, implying a positive regression of albumen height with egg weight. However, several studies have shown that although the egg weight and total amount of albumen increase with the age of the hen, the albumen height decreases linearly, and the correctness of using the Haugh unit has been questioned (Silversides, 1994; Silversides and Scott, 2001).

In the present trial, neither the height of albumen nor Haugh unit were affected by diet composition. According to a review on factors affecting albumen height (Williams, 1992), nutrition is not a factor of major importance for that trait. In agreement with this, there are several examples of recent studies on diets with different inclusions of shrimp head meal (Carranco-Jáuregui et al., 2006) or DDGS (Świątkiewicz and Koreleski, 2008) in which no effect of diet composition on albumen height was found.

The higher scores for yolk color, implying a stronger colored yolk, in eggs from hens fed the mussel meal diets compared with the conventional and the DDGS diets, was expected. In agreement, Jönsson and Elwinger (2009) when comparing feeds with fractions of mussel or fish meal found a stronger yolk color with the former. Yolk pigmentation is dependent on the accumulation of carotenoids such as xanthophylls, which hens are unable to synthesize (Nys, 2000). Algae can synthesize carotenoids and as blue mussels consume microalgae, they become rich in carotenoids. In the present study, the standard organic diet generated a yolk pigmentation similar to the 3.5% mussel meal diet. The strong pigmentation of standard organic egg yolks was probably due to the fraction of maize gluten meal (9%) included in the diet (Table 1) because maize gluten meal is rich in xanthophylls (Nys, 2000).

The higher percentage of blood spots found in eggs from the brown genotype, HB, compared with the white HW hens is a common finding (Abrahamsson et al., 1996) and is possibly inherited. The significantly lower proportion of dirty eggs found in eggs from the brown HB hens is most probably due to the fact that dirty spots are more easily detected in white-shelled eggs than brown (Wall and Tauson, 2007).

Diets increasing the moisture of birds' excreta may lead to elevated levels of dirty eggs (Smith et al., 2000). In the present study, the 7.0% mussel meal diet generated significantly lower manure DM than the diet with 3.0% mussels, and there was a tendency of higher percentage of dirty eggs in the former compared with the latter diet. This is in agreement with Jönsson et al. (2009), who found a lower manure DM with the 7.0% mussel meal diet when evaluating the same mussel meal diets and standard organic diet as in the present study but in an organic housing environment. However, because the mussel meal diets differed in others aspects than inclusion level of mussel meal, it cannot be excluded that other differences in diet composition may have had effect of manure DM.

In conclusion, with the fractions of DDGS and mussel meal used in the present study, no negative effects on egg odor or flavor were detected. The majority of egg quality traits were unaffected by the diets studied. The DDGS diet generated eggs with characteristics very similar to eggs from hens fed the conventional standard diet. Possible effects of mussel meal on manure DM and percentage of egg yolk need to be further evaluated using diets less different in levels of other feed ingredients.

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