SHRIMP HEAD MEAL IN LAYING HEN RATIONS AND ITS EFFECTS ON FRESH AND STORED EGG QUALITY

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SUMMARY

*In order to determine the effects of shrimp (*Penaeus *spp.) by-product meal (SBM) on performance parameters, physical quality and sensory evaluation of fresh and stored eggs, 120 white Leghorn hens, 42 weeks old, were distributed in 4 replicates of five treatments (0, 10, 15, 20 and 25% SBM). At 28 days of the assay, eggs were collected from each treatment to evaluate physical quality at 0, 15 and 30 days of storage at 4 and 20ºC. A factorial design of 5×3×2 was used. There were no statistical differences in performance parameters (P>0.05). Average egg weight was higher (64.08g) with 15% SBM, without any detectable effect due to storage time. Haugh Units (HU) decreased in eggs stored at 20ºC (15 and 30 days), but not at 4ºC. Yolk color was reduced in treatments with SBM as compared with the control and was also altered by storage time at 20ºC. Eggshell weight was not affected by storage conditions or by the treatments. No differences (P>0.05) in eggshell thickness and sensorial evaluation (yolk color and taste) were found. It is concluded that the differences found were caused by storage time and temperature, not by the inclusion of SBM in laying hens' rations.*

RESUMEN

*Para conocer el efecto de la harina (HCC) de cabezas de camarón (*Penaeus *spp.) sobre las variables productivas, la calidad física y evaluación sensorial del huevo fresco y almacenado, se utilizaron 120 gallinas Leghorn blancas de 42 semanas de edad, distribuidas en 5 tratamientos (0, 10, 15, 20 y 25% de HCC) con 4 repeticiones cada uno. A los 28 días del ensayo se recolectaron huevos de cada tratamiento para evaluar la calidad física a los 0, 15 y 30 días de almacenamiento a 4 y 20ºC, con un diseño factorial de 5×3×2. No hubo diferencias estadísticas (P>0,05) en las variables productivas. El peso promedio del huevo fue mayor (64,08g) con 15% de HCC, sin encontrarse efecto por el tiempo de almacenamiento. Las Unidades Haugh (UH) de los huevos almacenados a 20ºC por 15 y 30 días disminuyeron, pero no a 4ºC. El color de la yema fue menor en los tratamientos con HCC respecto al testigo y se vio afectado por el tiempo de almacenamiento a 20ºC. El peso del cascarón no varió con las condiciones de almacenamiento ni los tratamientos. En grosor de cascarón y en la evaluación sensorial (sabor y color de la yema), no hubo diferencias (P>0,05). Se concluye que las diferencias encontradas se debieron al tiempo y temperatura de almacenamiento y no a la inclusión de HCC en las raciones para gallinas ponedoras.*

Introduction

The preference for the high nutritional value and low cost of eggs has made Mexico the number one consumer of eggs worldwide. Consumer preference is based first on egg quality and second on freshness (Guerra, 2000). Therefore, it is important that egg quality be evaluated according to the factors that stimulate consumer purchases such as egg size, eggshell resistance and color, albumen quality, yolk color, flavor and freshness.

Fresh eggs are those that maintain optimal sensorial, physical, chemical and microbiological characteristics (Norma Mexicana, 2004). Like other foods of animal origin, eggs are generally stored at 4ºC for up to 25 days without spoiling. Freshness is recognized when the yolk remains in the center of the albumen. Although eggs are rarely consumed on the day they are laid, if eggs are properly handled, their quality remains during storage (Charley, 2004).

Previous studies (Rosenfeld *et al*., 1997; Carranco *et al*., 2003) on the addition of shrimp industry by-products, such as shrimp heads, have demonstrated that they are a source of protein and pigment. In Mexico, 60000tons per year of this by-product is produced and its disposal represents a problem (Casas y Ponce, 1999). Most of

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RESUMO

Para conhecer o efeito da farinha (FCC) de cabeças de camarão (Penaeus spp.) sobre as variáveis produtivas, a qualidade física e avaliação sensorial do ovo fresco e armazenado, se utilizaram 120 galinhas Leghorn brancas de 42 semanas de idade, distribuídas em 5 tratamentos (0, 10, 15, 20 e 25% de FCC) com 4 repetições cada um. Aos 28 dias do ensaio se recolheram ovos de cada tratamento para avaliar a qualidade física aos 0, 15 e 30 dias de armazenamento a 4 e 20ºC, com um desenho fatorial de 5×3×2. Não houve diferenças estatísticas (P>0,05) nas variáveis produtivas. O peso médio do ovo foi maior (64,08g) com 15% de FCC, sem encontrar-se efeito pelo tempo de armazenamento. As Unidades Haugh (UH) dos ovos armazenados a 20ºC por 15 e 30 dias diminuíram, mas não a 4ºC. A cor da gema foi menor nos tratamentos com FCC em relação à testemunha e se viu afetado pelo tempo de armazenamento a 20ºC. O peso da carcaça não variou com as condições de armazenamento nem os tratamentos. Na espessura da carcaça e na avaliação sensorial (sabor e cor da gema), não houve diferenças (P>0,05). Conclui-se que as diferenças encontradas se deveram ao tempo e temperatura de armazenamento e não à inclusão de FCC nas rações para poedeiras.

it is discarded at sea or in municipal dumps rather than being used by the balanced feed industry.

Studies on the chemical composition of this by-product, as well as about the appropriate levels of inclusion in different laying hen diets, are necessary in order to know the effect they may have when incorporated into laying hen rations. Sorghum and soy bean meal are frequently used ingredients in mexican broiler and laying hen diets to supply energy and protein respectively (Morales *et al*., 1992). In the case of laying hen diets, shrimp heads may be added to provide unsaturated fatty acids and pigmentation for egg yolks (carotenoids) and their inclusion should favor egg quality (Grobas and Mateos, 1996). Therefore, the purpose of this study was to know the effect of shrimp by-product meal (*Penaeus* spp.) on productive parameters and physical quality of eggs at different storage times and temperatures.

Materials and Methods

Chemical analysis of shrimp by-product meal

The shrimp by-product meal (SBM) was bought from *Proteinas Marinas y Agropecuarias S.A. de C.V.* in Guadalajara, Jalisco, Mexico. The crude protein, ether extract, ash, moisture, total carbohydrates and minerals (Na, Ca and Mg) were determined using methods described in AOAC (2000), gross energy by Parr a calorimetric bomb (Parr Instrument Company, Inc., Moline Illinois) and microbiological analysis (aerobic, coliform, and *E.coli* counts, and *Salmonella* detection) were done according to Colón and Morales (1995).

Birds and diets

One-hundred and twenty Isa Babcok-B-300 laying hens of 42 weeks of age (1.5-2.0kg weight), in their first laying cycle, were randomly distributed into 5 treatments consisting in 0, 10, 15, 20 and 25% SBM inclusion into commercial sorghum-soybean diets in which the soybean was partially replaced, with four replicates each. Each replicate included 6 hens (2 hens per cage). Water and feed were offered *ad libitum* during the 28 days experiment. Diets met the nutritional recommendations for laying hens according to NRC (1994).

Data recording

Egg production, egg weight and feed intake were measured daily. Feed conversion (feed intake per kg egg produced), egg mass (percentage hen-day egg production × average individual egg weight in grams per egg) and egg production were calculated.

Collection and physical evaluation of eggs

At the end of 4 weeks (days 28-31) 72 eggs were analyzed with the use of a semi-automated egg quality system (Technical Service and Supply Inc., England, UK). Egg weight, albumen height, Haugh Units, eggshell thickness, eggshell weight and yolk color according to the Roche Color Fan, were measured on fresh eggs and eggs stored for 15 or 30 days at 4 or 20ºC. The egg quality system was based on a microprocessor (QCM+) connected to a digital balance and an albumen height measurement electronic gauge (Technical Service and Supply Inc., England, UK). The QCM+ collected data from the in-line instruments and displayed a reading, after which the data were transferred to a computer fitted with Eggware software (Technical Service and Supply Inc., England, UK). The Haugh Units (HU) of the albumen were calculated by a software using the HU formula (Eisen *et al*., 1962). Shell thickness was measured near the equator of the egg with a micrometer. The pH of the whole egg was determined by a Hand-Held pH-Tester (Cole-Parmer).

Sensory evaluation

This test was performed in single booths and under white light, in the Sensorial Evaluation Laboratory. Thirty individuals of both sexes, who were usual egg consumers participated in sensory evaluations as non-trained panelists. Sensory evaluations were carried out on fresh eggs as well as eggs stored at 4 and 20ºC for 15 and 30 days. Level of agreeability was measured (Hedonistic Test) for egg flavor, evaluating level of pleasure or displeasure (Pedrero and Pangborn, 1996). The Preference Test was used to evaluate yolk color, with the purpose of selecting by level of preference a series of samples according to the personal agreeability (Pedrero and Pangborn, 1996).

Statistical analysis

The data that were obtained for the different variables were subjected to variance analysis according to a factorial arrangement 5×3×2 (SBM concentration, time and temperature). Differences among means were analyzed with Tukey's test, with a confidence level of 95%, by GLM Linear procedures (SAS, 1991). The egg yolk color preference was calculated according to the Friedman Test ($P<0.05$; Steel and Torrie, 1985).

Results

The chemical composition of shrimp by-product meal (SBM) is indicated in Table I. The experimental diet formulas used for laying hens, with different inclusion percentages of SBM are

TABLE I
CHEMICAL COMPOSITION AND MICROBIOLOGICAL ANALYSIS OF SHRIMP BY-PRODUCT MEAL

Components	
Moisture (g/100g)	9.027 ±0.01
Ash (g/100g)	29.863 ±0.03
Ether extract (g/100g)	0.880 ±0.03
Crude protein (N×5.4, g/100g)	36.072 ±0.26
Total carbohydrates (g/100g)	24.158
Gross energy (kcal/g)	2.447 ±0.09
Calcium (mg/100g)	4581.29 ±0.15
Sodium (mg/100g)	104.59 ±0.28
Magnesium (mg/100g)	414.02 ±0.21
Mesophyllic aerobe bacteria (CFU/g)	2000000
Total coliforms (MPN/g)	9.3
Fecal coliforms (MPN/g)	0.9
Salmonella sp. (25g)	Negative
Escherichia coli (MPN/g)	<0.3

The values presented are mean ±SE of 6 samples. CFU: colony forming units, MPN: most probable number.

presented in Table II. Diets were isocaloric and isonitrogenous.

Performance parameters

The results obtained with the different diets used were similar to the control group with regard to average egg weight, egg production, feed conversion, feed intake, egg mass and number of eggs produced (P>0.05; Table III).

Egg physical quality

In the physical quality study (Table IV) the average egg weight did not show differences when kept refrigerated (P>0.05) at 0, 15 and 30 days. Nevertheless, with the inclusion level of 15% SBM, weight (63.74g) was higher (P<0.05) than in treatments with 0 and 10%. The average egg weight at 20°C presents differences (P>0.05) at 15 and 30 days. There were no differences (P>0.05) between SBM inclusion levels.

Albumin height (Table V), as well as Haugh Units (HU; Table VI), presented a similar behavior. When kept at 4°C there were statistical differences (P<0.05) due to the fact that at 15 days their value was lower than in fresh eggs, while at 30 days an increase was detected. At 20°C, these variables decreased as storage time increased (P<0.05).

Egg yolk color (Table VII) decreased (P<0.05) as SBM levels increased, both at 4°C and at 20°C. For storage time, color did not diminish at 4°C temperature; while at 20°C at 30 days there was a reduction of 9.91 to 8.33 on average.

While SBM is a good source of Ca, among other minerals, when it was added to the laying hen formula the weight of the shell was not affected (P>0.05; Table VIII) by storage at 4°C; but increased in relation to the control group at 15 and 20% SBM levels. This perhaps

TABLE II
FORMULAS OF LAYING HEN RATIONS INCLUDING SHRIMP BY-PRODUCT MEAL (SBM)

Ingredients	0%	10%	15%	20%	25%
Sorghum	685.649	629.878	602.697	575.516	548.336
Soybean	185.076	131.898	104.963	78.028	51.093
SBM	–	100.000	150.000	200.000	250.000
Calcium carbonate	101.555	99.398	98.321	97.244	96.167
Calcium Orthophosphate	13.320	13.983	14.313	14.643	14.973
Soy oil	4.682	15.617	20.758	25.899	31.040
Sodium chloride	3.622	3.334	3.190	3.046	2.902
Vitamins + Minerals[a]	2.500	2.500	2.500	2.500	2.500
Micoad [b]	1.000	1.000	1.000	1.000	1.000
Avelut powder [c]	1.000	1.000	1.000	1.000	1.000
Avired [d]	0.030	–	–	–	–
Methionine 98	0.916	0.642	0.508	0.373	0.239
Choline chloride 60	0.500	0.500	0.500	0.500	0.500
Furacyl [e]	0.150	0.150	0.150	0.150	0.150
Calculated nutrient					
Crude protein, %	15.0	15.205	15.301	15.397	15.493
ME, Kcal/g	2750	2750	2750	2750	2750
Calcium, %	4.000	4.000	4.000	4.000	4.000
Available P, %	0.370	0.370	0.370	0.370	0.370
Methionine, %	0.347	0.355	0.359	0.363	0.368
Methionine + cystine, %	0.490	0.596	0.596	0.596	0.596
Lysine, %	0.709	0.845	0.912	0.979	1.046

* in mg/kg.
a: vitamins and minerals mix, per kg, for laying hens: 3.5744×10^6IU vit. A, 1.344×10^6IU vit. D_3, 3.216×10^3IU vit. E, 1.112g vit. K_3, 2.228g vit B_1, 8.96g Niacin, 5.592g Pantothenic acid, 0.004g Cyanocobalamin, 160g Choline, 0.016g antioxidant, 0.04g Co, 12.0g Fe, 0.04g I, 24g Mg, 14g Zn, 0.04 Se, 0.6g Cu. b: mycotoxin sequestrant, c: saponified xanthophylls of Aztec marigold (yellow, 15ppm), d: red xanthophylls (cantaxanthin, 10 ppm), e: Furazolidon-bacitracin-zinc.

TABLE III
AVERAGE RESULTS OF PERFORMANCE PARAMETERS OF HENS FED WITH DIFFERENT SHRIMP BY-PRODUCT MEAL (SBM) INCLUSION LEVELS

SBM (%)	Egg production (%)	Egg weight (g)	Feed conversion	Feed intake bird/day/g	Egg mass (g)
0	84.96 ±0.21	61.26 ±1.54	2.15 ±0.28	108.07 ±3.69	51.94 ±4.32
10	78.26 ±7.99	62.17 ±1.41	2.19 ±0.25	105.55 ±2.84	48.50 ±5.34
15	84.66 ±1.88	61.78 ±0.51	2.20 ±0.26	110.86 ±2.41	52.32 ±3.18
20	79.31 ±3.57	61.10 ±1.46	2.23 ±0.28	110.17 ±5.18	48.40 ±5.76
25	74.99 ±8.41	61.45 ±1.32	2.28 ±0.35	107.66 ±4.63	45.43 ±9.25

There were no statistical differences for each treatment (P>0.05).

TABLE IV
AVERAGE EGG WEIGHT (g) OF 44 WEEKS-OLD HENS, FED WITH DIFFERENT LEVELS OF SHRIMP BY-PRODUCT MEAL (SBM) INCLUDED IN THEIR DIETS

	Refrigeration (4°C)				Room temperature (20°C)		
SBM (%)	Day 0	Day 15	Day 30	Average	Day 15	Day 30	Average
0	57.43 ±0.64	62.49 ±0.47	59.39 ±0.75	59.77 b	60.51 ±0.93	52.82 ±4.50	56.92 a
10	61.55 ±1.54	58.24 ±5.38	58.64 ±0.93	59.48 b	61.55 ±1.16	58.60 ±1.14	60.57 a
15	64.08 ±0.76	64.19 ±0.61	62.96 ±1.07	63.74 a	61.92 ±1.12	57.56 ±1.11	61.19 a
20	61.06 ±0.90	63.56 ±1.07	62.43 ±0.87	62.34 ab	58.39 ±1.06	54.77 ±0.82	58.07 a
25	60.67 ±0.84	61.46 ±0.61	60.68 ±1.21	60.94 ab	61.80 ±1.02	53.22 ±4.99	58.56 a
Average	60.96 a	61.99 a	60.82 a		60.83 a	55.39 b	

The values presented are mean ±SE. Different letters indicate statistical differences (P<0.05) in average row and average columns.

was due to the fact that the diet was formulated with added Ca.

Eggshell thickness was not affected by any of the variables of the experiment (concentration, time and temperature) as there were no statistical differences between any of them.

Sensory evaluation

No differences (P>0.05) were found in the variables studied for egg flavor and yolk color, among the five treatments and egg storage conditions.

Discussion

The chemical composition of SBM used in this study shows a high ash content (29.86%), these fractions correspond to mineral salts, that form the cephalothorax of shrimp this can have to the concentration of mineral salt in the season of capture, as well as of the age of the crustaceans (Castro *et al*., 1995). The largest fraction in SBM was crude protein (36.07%).

The diets used complied with NRC (1994) recommendations. They were isocaloric and isonitrogenous. Furthermore, the diets with SBM did not have red pigment added to them, since the main carotenoid of SBM is astaxanthin, a red pigment which substitutes the pigment added to the control diet (cantaxanthin), in order to reduce costs.

Performance parameters

For performance parameters, egg production, egg weight, feed conversion, feed intake, egg mass and produced eggs, there were no statistical differences (P>0.05) among the different SBM levels.

Rosenfeld *et al*. (1997) carried out studies with shrimp meal, including it in broiler rations at 10, 20, 30, 40, 60, 80 and 100% soy bean partial replacement; from 10 to 40%, no statistical differences were found (P>0.05) in weight per bird, feed intake, and feed conversion parameters, without any mortality, which is in agreement with the productive parameters detected in the present study, in laying

TABLE V
AVERAGE ALBUMEN HEIGHT (MM) OF EGGS FROM 44 WEEKS-OLD HENS, FED WITH DIFFERENT LEVELS OF SHRIMP BY-PRODUCT MEAL (SBM) INCLUDED IN THEIR DIETS

	Refrigeration (4ºC)				Room temperature (20ºC)		
SBM (%)	Day 0	Day 15	Day 30	Average	Day 15	Day 30	Average
0	6.36 ±0.29	5.24 ±0.76	5.77 ±0.23	5.84 a	4.43 ±0.14	2.50 ±0.11	4.43 a
10	7.33 ±0.53	5.01 ±0.46	5.65 ±0.19	6.03 a	3.78 ±0.21	3.01 ±0.10	4.71 a
15	7.56 ±0.48	4.94 ±0.34	5.34 ±0.37	5.95 a	4.00 ±0.27	2.51 ±0.12	4.69 a
20	7.18 ±0.24	5.45 ±0.34	6.26 ±0.26	6.30 a	3.92 ±0.27	2.98 ±0.25	4.69 a
25	5.76 ±0.47	5.57 ±0.34	6.31 ±0.37	5.88 a	4.23 ±0.17	2.80 ±0.26	4.30 a
Average	6.36 a	5.24 b	5.87 c		4.07 b	2.76 b	

The values presented are mean ±SE. Different letters indicate statistical differences (P<0.05) in average row and average columns.

TABLE VI
AVERAGE HAUGH UNITS (HU) OF EGGS FROM 44 WEEKS-OLD HENS, FED WITH DIFFERENT LEVELS OF SHRIMP BY-PRODUCT MEAL (SBM) INCLUDED IN THEIR DIETS

	Refrigeration (4ºC)				Room temperature (20ºC)		
SBM (%)	Day 0	Day 15	Day 30	Average	Day 15	Day 30	Average
0	79.59 ±2.04	50.50 ±9.46	74.71 ±1.74	68.27 a	62.46 ±1.48	42.52 ± 455	61.52 a
10	84.16 ±2.60	61.12 ±5.80	74.18 ±1.52	73.15 a	54.05 ±2.26	46.30 ± 130	61.50 a
15	84.93 ±2.46	65.23 ±2.59	68.31 ±4.45	72.82 a	56.17 ±2.93	38.75 ± 199	59.95 a
20	83.96 ±1.65	69.60 ±3.53	77.23 ±2.04	76.93 a	57.28 ±3.09	47.49 ± 316	62.91 a
25	72.16 ±4.76	77.67 ±2.86	77.67 ±2.86	73.75 a	59.53 ±1.85	39.14 ± 415	56.94 a
Average	80.96 a	63.57 c	74.42 b		57.90 b	42.84 c	

The values presented are mean ±SE. Different letters indicate statistical differences (P<0.05) in average row and average columns.

TABLE VII
AVERAGE YOLK COLOR (ROCHE FAN) OF EGGS FROM 44 WEEKS-OLD HENS, FED WITH DIFFERENT LEVELS OF SHRIMP BY-PRODUCT MEAL (SBM) INCLUDED IN THEIR DIETS

	Refrigeration (4ºC)				Room temperature (20ºC)		
SBM (%)	Day 0	Day 15	Day 30	Average	Day 15	Day 30	Average
0	11.66 ±0.22	8.50 ±1.48	11.66 ±0.30	10.61 a	11.41 ±0.14	11.00 ±0.24	11.36 a
10	9.75 ±0.21	9.50 ±0.89	9.16 ±0.24	9.47 ab	9.33 ±0.14	8.16 ±0.24	9.08 b
15	9.50 ±0.19	9.58 ±0.14	9.08 ±0.28	9.38 b	9.50 ±0.15	7.33 ±0.35	8.77 b
20	9.41 ±0.25	9.75 ±0.13	8.75 ±0.21	9.30 b	9.83 ±0.11	7.91 ±0.19	9.05 b
25	9.50 ±0.23	9.08 ±0.19	8.83 ±0.20	9.13 b	9.50 ±0.15	7.25 ±0.71	8.75 b
Average	9.96 a	9.28 a	9.50 a		9.91 a	8.33 b	

The values presented are mean ±SE. Different letters indicate statistical differences (P<0.05) in average row and average columns.

TABLE VIII
AVERAGE SHELL WEIGHT (G) OF EGGS FROM 44 WEEKS-OLD HENS, FED WITH DIFFERENT LEVELS OF SHRIMP BY-PRODUCT MEAL (SBM) INCLUDED IN THEIR DIETS

	Refrigeration (4ºC)				Room temperature (20ºC)		
SBM (%)	Day 0	Day 15	Day 30	Average	Day 15	Day 30	Average
0	5.21 ±0.10	5.15 ±0.48	5.51 ±0.12	5.29 a	5.50 ±0.12	5.57 ±0.12	5.43 a
10	5.60 ±0.17	5.52 ±0.52	5.58 ±0.13	5.57 ab	5.84 ±0.19	5.73 ±0.22	5.73 a
15	5.98 ±0.09	6.08 ±0.13	5.87 ±0.13	5.98 a	5.97 ±0.13	5.75 ±0.09	5.90 a
20	5.72 ±0.15	5.94 ±0.19	5.95 ±0.14	5.87 a	5.51 ±0.16	5.05 ±0.48	5.42 a
25	5.60 ±0.05	5.80 ±0.70	5.65 ±0.22	5.68 ab	5.80 ±0.08	5.29 ±0.49	5.56 a
Average	5.62 a	5.70 a	5.71 a		5.73 a	5.46 a	

The values presented are mean ±SE. Different letters indicate statistical differences (P<0.05) in average row and average columns.

hens. Similar results were also obtained by Damron *et al*. (1964) and Raab *et al*. (1971), who incorporated shrimp meal at 9.1 and 6.8% in broiler diets, without finding statistical differences in yield. Ilian *et al*. (1985) used shrimp meal, including other species of secondary importance, at levels above 10%, finding no negative effect on broiler productive variables. Nevertheless, at 60-100% levels, statistical differences were found ($P<0.05$) in broiler weight (Rosenfeld *et al.,* 1997).

Physical quality of eggs

Interior egg quality was examined in this study to determine if the different levels of SBM and storage would alter quality of eggs. The Mexican Official Standard for poultry products (Norma Mexicana, 2004) classifies eggs according to their average weight in three classes: Mexico Extra (61-65g), Mexico 1 (60-55g) and out of classification (<55g). Significant differences were found in relation to average egg weight with the levels of SBM inclusion, perhaps due to the loss of moisture inside the egg, making the eggshell thinner and more fragile (Ahn *et al*., 1999; Scott and Silversides, 2000). Authors such as Silversides and Scott (2001) studied egg weight and albumen height, confirming there is no relationship between these two measurements. However, they found statistical differences with storage time and age of hens.

Albumen height and Haugh Units (HU) are valuable parameters that influence egg quality (Villa, 2001). In general, albumen height oscillates between 6.04 and 6.72 (Godínez *et al*., 1984) and HU has values between 70 and 80 (Sliusar, 1972; Villa *et al*., 1987). In the present study, average albumen height and Haugh Units (HU) of eggs stored at 20ºC (15 and 30 days) decreased in relation to those of fresh eggs (6.36, 4.07 and 2.76mm; 80.96, 57.90 and 42.84HU). This did not happen at 4ºC, due to an unknown reason, albumen height and HU were larger at 30 days as compared to 15 days (5.87 and 5.24mm; 74.42 and 63.57HU).

The effect of albumen height and HU reduction could have been due to an increase in pH, since in fresh eggs it was 7.1, while at 15 and 30 days at 20ºC it increased to 7.9 and 8.2, respectively, while under refrigeration it remained at 7.2 and 7.6, at 15 and 30 days. Changes in pH imply modifications in albumen proteins, so that it becomes thinner and looses CO_2, allowing rupture of the electrostatic complex between lysozyme and ovomucin (Scott and Silversides, 2000; Silversides and Scott, 2001). These variables were not affected by different inclusions of SBM ($P>0.05$; Solomon, 1991; Guerra, 2000).

Shrimp by-product meal has carotenoid pigments (astaxanthin) that are used for pigmentation of salmon, trout, chicken skin and egg yolk. Nevertheless, astaxanthins present in the cephalothorax of shrimp are associated to protein, chitin, and mineral salts, forming stable complexes that are an obstacle for pigment absorption in these species and, therefore, there is a low absorption of astaxanthin, which has an effect on final coloring (Hudon, 1994; Leeson and Summers, 2001). In this study, statistical differences were found ($P<0.05$) among SBM inclusion levels and storage conditions at 20ºC and 30 days. Control diet promotes higher yolk color (11.66), and on average 10.61 using a synthetic pigment (capsaicin) that is free of protein complexes that allow a better absorption of it. However, the color value obtained with SBM on the Roche scale (9.47 to 9.13) was not considered low in eggs stored at 4ºC, while those stored at 20ºC showed higher losses at 30 days, and with 25% it reached 8.75, which is considered to be a low color.

Poor eggshell quality represents losses for the producer, distributor and final sale point, due to breakages that can take place at laying, collection following lay, cleaning, handling and transportation. Eggshell fragility is increased in direct proportion to weight/size of the egg and temperature. When room temperature is above 20ºC eggshell fragility problems are detected. Formulas that link Ca with factors that intervene in its metabolism (vitamin D3) and transportation, as well as blood plasma pH regulators provide a wide range of action to achieve the desired eggshell hardness (Scott and Silversides, 2000; Silversides and Scott, 2001).

Sensorial evaluation

For egg flavor, panelists did not detect fish odor or flavor when SBM was not included. The egg yolk color was no affected by the SBM inclusion in the laying hens diets.

The results suggest that shrimp by-product meal could be used in the laying hens rations. The advantage that it has is that it is a renewable resource, an economical raw material and, furthermore, it is a good source of protein, minerals and pigments. The inclusion of up to 25% shrimp by-product meal in laying hen rations did not affect productive variables nor physical quality of eggs. Insofar as time and storage temperature, the differences observed were due to the normal deterioration that any food suffers during prolonged shelf life.

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