

Efecto de la concentración de proteína en la dieta sobre rendimiento productivo, características de la canal y composición química de carne de pollos de engorda en el trópico seco

Effect of protein concentrations in the diet on productive performance, carcass characteristics, and meat chemical composition of broiler chickens in the dry subtropics

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Resumen

Introducción: Las dietas actuales de pollos de engorda, tienden a incrementar los niveles de proteína para obtener variables productivas altas que son logradas en forma conjunta con mejoras genéticas, de manejo, sanitarias, entre otras. Sin embargo, el incremento en los niveles de proteína en la dieta no siempre acompaña el incremento en eficiencia productiva de los pollos de engorda debido a múltiples factores que intervienen en el sistema de producción. El objetivo de esta investigación fue evaluar el efecto de niveles crecientes de proteína cruda (PC) en las dietas sobre el comportamiento productivo, las características de la canal y la composición química de la carne de pechuga y muslo de pollos de engorde en el trópico seco.

Método: El estudio incluyó 200 pollos de engorde Ross de 1 día de edad. Las dietas de tratamientos (T) para las fases de inicio y finalizado tuvieron concentración de proteína cruda (PC; %) de: 21 y 18.1 (T1); 21.4 y 18.5 (T2); 21.8 y 18.9 (T3); 22.2 y 19.3 (T4), respectivamente. Dentro de cada una de las fases de alimentación, las cuatro dietas de tratamiento fueron formuladas con niveles similares de energía metabolizable aparente. En un diseño completamente aleatorio, las aves fueron asignadas a los cuatro tratamientos con cinco réplicas (corrales de piso) de 10 aves cada una. El ensayo se dividió en dos fases (inicio y finalizado) de 21 días cada una (42 días en total).

Resultados: La concentración de proteínas no tuvo ningún efecto ($P > 0.05$) en el aumento de peso, mientras que el consumo de alimento fue mayor en T1 ($P < 0.05$) que en T2 y T3. La conversión alimenticia fue mejor en T2 y T4 ($P < 0.05$) que en T1. No hubo influencia del tratamiento en el peso o en los cortes de la canal ($P > 0.05$). El rendimiento de la canal fue mayor ($P < 0.05$) en T1 que en T3. La materia seca y el extracto etéreo de la carne de la pechuga y el muslo fueron similares ($P > 0.05$) entre los tratamientos. La proteína cruda de la pechuga fue mayor ($P < 0.05$) en T2 que en T3. La menor ($P < 0.05$) concentración de PC en la carne de muslo fue en T3.

Discusión o Conclusión: Estos resultados indican que en la zona subtropical del noreste de México los aumentos de PC sobre los valores de T2 (21.4% y 18.5% PC en dietas de inicio y finalizado, respectivamente) no mejoraron el rendimiento productivo, las características de la canal o la composición química de la carne de pollos de engorde.

Palabras clave: alimento; nutrientes; aves; producción; harina de soya; proteína; dieta; eficiencia productiva; pollos; peso; consumo de alimento; comportamiento productivo; carne; materia seca; extracto etéreo; zona subtropical de México; composición química

Abstract

Introduction: Current diets of broiler chickens tend to increase protein levels to obtain high productive variables that are achieved in combination with genetic, management, and sanitary improvements, among others. An increase in dietary crude protein levels does not always accompany an increase in broiler productive efficiency due to multiple factors involved in the production system. The objective of this study was to evaluate the effect of increasing levels of dietary crude protein (CP) on productive performance, carcass characteristics, and chemical composition of breast and thigh meat in broiler chickens raised in the dry subtropics of northeastern Mexico.

Method: The study used 200, 1-day-old male Ross broiler chicks. In a completely randomized design, birds were allocated to the four treatments with five replicates (floor pens) of ten birds each. The trial was divided in two phases (starter and finisher) of 21 days each (42 days total). Treatment diets (T) for starter and finisher phases had crude protein concentrations (CP; %) of 21 and 18.1 (T1), 21.4 and 18.5 (T2), 21.8 and 18.9 (T3), and 22.2 and 19.3 (T4), respectively. Within each feeding phase, the four treatment diets were formulated to similar levels of apparent metabolizable energy.

Results: Protein concentrations had no effect ($P > 0.05$) on weight gain, while feed intake was greater in T1 ($P < 0.05$) than in T2 and T3. Feed conversion was better in T2 and T4 ($P < 0.05$) than in T1. There was no influence of treatment on carcass weight or carcass cuts ($P > 0.05$). Carcass yield was greater in T1 than in T3 ($P < 0.05$). Breast and thigh dry matter and ether extracts were similar ($P > 0.05$) between treatments. Breast crude protein was greater ($P < 0.05$) in T2 than in T3. The lowest ($P < 0.05$) CP concentration in thigh meat was in T3.

Discussion or Conclusion: These results indicated that in the dry subtropics area of northeastern Mexico increases in CP above the level of T2 (21.4% and 18.5% CP in starter and finisher diets, respectively) did not improve broiler chicken productive performance, carcass characteristics or meat chemical composition.

Keywords: feed; nutrients; poultry; production; soybean meal; protein; diet; productive efficiency; chickens; weight; food consumption; productive performance; meat; dry matter; ether extract; subtropical area of Mexico; chemical composition

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Introduction

The poultry industry in 2018 generated 63.3% of animal production in Mexico; of the total, 34.9% was broiler chickens. Chicken meat is an important food for Mexican consumers. Animal protein intake was 39% from chicken, compared to 16% from beef and 8% from pork. In Mexico, per capita consumption in 2018 was 23 kg of broiler chicken meat (UNA, 2019).

Soybean meal is the preferred vegetable protein source for poultry diets. It contains 40 to 48% crude protein (CP), depending on the amount of hulls removed and the oil extraction procedure used. Adequately processed, soybean meal is an excellent source of protein for all kinds of poultry; however, soybean meal is expensive when compared with other protein rich ingredients of vegetal source. In Mexico, approximately 90% of broiler production costs are represented by the cost of feed plus the cost of the chicks (UNA, 2019). Therefore, it is necessary to identify alternatives for optimal protein rich ingredients to include in the broiler diet, and also to optimize the quality of the broiler meat produced.

The results of broiler productive performance have not been conclusive when different levels of dietary CP are used. Houshmand *et al.* (2012) observed better growth performance of broiler chickens fed diets containing 23.4% and 20.2% CP for starter and finisher phases, respectively, than in birds fed diets with 15% less protein. Jafarnejad *et al.* (2010) reported improved productive performance in broilers (1 to 21 days) fed higher dietary protein levels (23% vs. 21% CP). In starter broiler chickens, the optimum dietary CP level has been established at 24.1% (Faridi *et al.*, 2012) and 24.5% (Faridi *et al.*, 2015). In another study, Abdel-Maksoud *et al.* (2010) reported maximum body weight in starter broiler chickens with lower dietary CP levels. Considering warmer environments, Laudadio *et al.* (2012a) and Amiri *et al.* (2019) reported no effect of dietary CP levels on broiler growth performance. However, Zulkifli *et al.* (2018) observed reduced growth performance of broilers under heat stress and fed low-CP diets.

Carcass characteristics and meat composition of broiler chickens have also been quite variable after feeding different levels of crude protein. In several studies, carcass characteristics

were not influenced by dietary CP levels (Mandal *et al.*, 2010; Oliveira *et al.*, 2013; Miranda *et al.*, 2015). In contrast, other researchers reported improved carcass characteristics with increased CP in the diet (Gheorghe *et al.*, 2013a; Gheorghe *et al.*, 2013b; Laudadio *et al.*, 2012b; Dehghani and Jahanian 2016). Increased dietary protein levels have reduced lipid deposition in broiler muscle (Marcu *et al.*, 2012; Marcu *et al.*, 2013). However, Gómez *et al.* (2011) found no effect of dietary CP on carcass protein deposition.

The genetic development of broiler chickens is continually generating better performing animals. Aftab (2019) documented reduction in time at slaughter weight (2.3 kg) from 52 d in 1995 to 36 d in 2017; breast yield also has been increased. The author identified nutrient density increase in diets of broiler chicken, particularly protein (amino acids). As discussed, nutrition is directly related to this development, so revisions and updates must be constantly undertaken in order to define new protein, energy, and nutritional requirements for each particular productive zone (Applegate and Angel, 2014). There are no conclusive reports about the productive performance of broiler chickens in the tropical hot and humid environments when fed diets with different crude protein levels. In these environments, CP level has not influenced growth of birds (Laudadio *et al.*, 2012a; Amiri *et al.*, 2019) or the productive performance has decreased when chickens were fed low-CP diets (Awad *et al.*, 2014). Therefore, the objective of this study was to assess the productive performance, carcass yield of major cuts, and chemical composition of breast and thigh meat of broiler chickens fed diets with increasing crude protein levels in the dry subtropical area of northeastern Mexico.

Method

Study area

The study was carried out on the poultry farm of the College of Veterinary Medicine and Animal Science of the Autonomous University of Tamaulipas, in Ciudad Victoria, Tamaulipas (dry subtropical area in northeastern Mexico) in the summer season. The area is located at 23°44'06"N and 97°09'50"W, at an altitude of 323 m. The mean annual rainfall is 926 mm, and the average temperature is 24 °C; in the summer, a maximum temperature of 40 °C is recorded, with thermal sensations of 45 °C and a minimum temperature of 22 °C (INEGI, 2017). These climatic characteristics are typical for the dry subtropics (ACw). During the present study the average, maximum and minimum temperatures were 28 °C, 40 °C and 22 °C, respectively.

Management and diets

All procedures involving animal care and management were in accordance with and approved by the Bioethics Committee of the College of Veterinary Medicine and Animal Science of the Autonomous University of Tamaulipas.

Two hundred, 1-day-old male Ross broiler chickens weighing 42 g on average were obtained from a commercial hatchery. Each treatment (diet) included 50 birds randomly assigned with five replications of ten animals each. During the entire experiment, birds were housed in 20 floor pens with wood shavings as litter. Twenty-four hours of light per day were provided during the entire trial. Each pen had an automatic drinker and a manually-filled feeder. Space allocation was at ten birds per square meter. Water and feed were offered *ad libitum*. Birds were vaccinated on day 7 of the trial against fowl pox (wing puncture) and against Newcastle (ocular) using the La Sota strain.

The chickens were raised following standard commercial practice. Two feeding phases were used: 1–21 and 22–42 days of age, for starter and finisher phases, respectively. There were four treatments (T) for starter and finisher diets crude protein (CP; %) levels: 21.0 and 18.1 (T1); 21.4 and 18.5 (T2); 21.8 and 18.9 (T3); 22.2 and 19.3 (T4), respectively. The diets of T2 corresponds to standard diets formulated according to the NRC tables; the T1 correspond a low-CP level, while T3 and T4 are had higher CP levels over the standard diet (T2). The CP increments

are equally spaced from T1 to T4. Dietary CP was increased by augmenting soybean meal in the diet, with small adjustments to the amounts of sorghum grain and vegetable oil to maintain the same levels of apparent metabolizable energy across diets. All diets were prepared according to National Research Council (NRC, 1994) poultry recommendations and are shown in **Tables 1** and **2**.

Body weight and feed intake were measured weekly on an electronic scale with a capacity of 40 kg (± 2 g; Rhino Model Bar-8, México) and feed conversion ratio (FCR; feed intake, g/weight gain, g) was calculated. At the end of the trial, two birds per cage, selected at random, were sacrificed by cervical dislocation (Mexican official law NOM 033-ZOO-1995) for carcass determinations and accessing chemical composition of breast and thigh meat. Carcass weight without viscera was used to estimate hot carcass yield. Then the carcass was dissected for main cuts: breast, thighs plus drumsticks, wings, back, trimmed back fat, liver, heart, and gizzard. These weights were recorded on an electronic scale with a capacity of 10 kg (± 1 g; Rhino Model BAPO-10, México). A sample of approximately 150 g from the left breast and thigh from each carcass was obtained and frozen (-20 °C) in nylon bags for 7 days, and then, laboratory analyses were performed. The samples were thawed at 4°C for 24 h and subsequently at room temperature until thawed. Muscle samples were analyzed for dry matter (oven at 105 °C for 24 h), ash (furnace at 550 °C for 3 h), ether extraction and crude protein (AOAC, 1990).

Statistical analyses

A completely randomized design with four treatments and five replicates was used in the statistical analysis. Dietary crude protein levels were the treatments compared. For growth performance (weight gain, feed intake, and feed conversion ratio) the replicate was the average of all broiler chickens in each pen. For carcass evaluation and meat chemical composition, the replicate was the average of two birds (selected at random) per pen. The percentage of dressed carcass yield was determined as carcass weight (g)/live weight (g). An analysis of variance with Tukey's test for

mean comparisons was applied. Statistical significance was declared at $P < 0.05$. For statistical analyses, the GLM procedures of SAS (2007) were used.

Table 1. Contents (percentages) of broiler experimental diets for the starter phase (1-21 days of age).

Tabla 1. Contenido (porcentajes) de dietas experimentales para pollos de engorde para la fase inicial (1-21 días de edad).

	T1 ¹ 21.0% CP	T2 21.4% CP	T3 21.8% CP	T4 22.2% CP
Ingredients				
Sorghum grain	61.35	59.86	58.58	57.19
Soybean meal	32.29	33.45	34.6	35.75
Vegetable oil	2.36	2.59	2.82	3.06
Premix ²	4	4	4	4
Total	100	100	100	100
Nutrient composition³				
CP, %	21.0	21.4	21.8	22.2
ME, kcal	2999.7	2999.5	2999.3	2999.8
Lysine	1.14	1.17	1.20	1.23
Methionine + Cystine	0.78	0.79	0.81	0.82

¹T = Treatment; CP = Crude Protein; ME = Metabolizable Energy.

²Premix for starter diets: monocalcium phosphate, calcium carbonate, common salt, growth promoter (BDM and 3-nitro), sodium monensin, mineral oil, ethoxyquin, retinol (vitamin A-acetate), cholecalciferol-D3 (vitamin D3), α -tocopheryl acetate (vitamin E), vitamin K3, riboflavin (vitamin B2), cobalamin (vitamin B12), niacin (vitamin B3), calcium D-pantothenate (vitamin B5), choline chloride (vitamin B4), butylated hydroxytoluene (BHT). **Calculated to contain:** 21.40% Ca; 8.10% total P; 3.40% Na; 0.80% L-lysine chlorhydrate; and 4.15% DL-methionine.

³Estimated from NRC (1994).

¹T = Tratamiento; CP = Proteína Cruda; ME = Energía Metabolizable.

²**Premezcla para dietas de inicio:** fosfato mono calcio, carbonato de calcio, sal común, promotor del crecimiento (BDM y 3-nitro), monensina sódica, aceite mineral, etoxinquin, retinol (vitamina A-acetato), colecalciferol-D3 (vitamina D3), acetato de tocoferilo (vitamina E), vitamina K3, riboflavina (vitamina B2), cobalamina (vitamina B12), niacina (vitamina B3), pantotenato D-calcio (vitamina B5), cloruro de colina (vitamina B4), hidroxitolueno butilado (BHT). **Calculado para contener:** 21.40% Ca; 8.10% total P; 3.40% Na; 0.80% L-lisina clorhidrato; y 4.15% DL-metionina.

³Estimado de NRC (1994).

Table 2. Contents (percentages) of broiler experimental diets for the finisher phase (22-42 days of age).

Tabla 2. Contenido (porcentajes) de dietas experimentales para pollos de engorde para la fase de finalizado (22-42 días de edad).

	T1 ¹ 18.1% CP	T2 18.5% CP	T3 18.8% CP	T4 19.3% CP
Ingredients				
Sorghum grain	68.53	67.12	65.76	64.37
Soybean meal	24.5	25.67	26.8	27.96
Vegetable oil	2.64	2.88	3.11	3.34
Premix ²	4	4	4	4
Pigment	0.33	0.33	0.33	0.33
Total	100	100	100	100
Nutrient composition³				
CP, %	18.1	18.5	18.9	19.3
ME, kcal	3085	3085	3085	3085
Lysine	0.92	0.95	0.98	1.01
Methionine + Cystine	0.73	0.74	0.76	0.77

¹T = Treatment; **CP** = Crude Protein; **ME** = Metabolizable Energy.

²**Premix for finisher diets:** monocalcium phosphate, calcium carbonate, common salt, growth promoter (BDM and 3-nitro), sodium monensin, mineral oil, ethoxyquin, retinol (vitamin A-acetate), cholecalciferol-D3 (vitamin D3), α -tocopheryl acetate (vitamin E), vitamin K3, riboflavin (vitamin B2), cobalamin (vitamin B12), niacin (vitamin B3), calcium D-pantothenate (vitamin B5), choline chloride (vitamin B4), butylated hydroxytoluene (BHT). **Pre-mix calculated to contain:** 19.80% Ca; 3.70% total P; 3.70% Na; 4.33% L-lysine chlorhydrate; and 5.15% DL-methionine.

³Estimated from NRC (1994).

¹**T** = Tratamiento; **CP** = Proteína Cruda; **ME** = Energía Metabolizable.

²**Premezcla para dietas de finalizado:** fosfato mono calcio, carbonato de calcio, sal común, promotor del crecimiento (BDM y 3-nitro), monensina sódica, aceite mineral, etoxinquin, retinol (vitamina A-acetato), colecalciferol-D3 (vitamina D3), acetato de tocoferilo (vitamina E), vitamina K3, riboflavina (vitamina B2), cobalamina (vitamina B12), niacina (vitamina B3), pantotenato D-calcio (vitamina B5), cloruro de colina (vitamina B4), hidroxitolueno butilado (BHT). **Premezcla calculada para contener:** 19.80% Ca; 3.70% total P; 3.70% Na; 4.33% L-lisina clorhidrato; y 5.15% DL-metionina.

³Estimado de NRC (1994).

Results

Growth performance

Results of productive performance of broiler chickens are shown in **Table 3**. For the starter phase (1-21 days), there was no effect ($P > 0.05$) of dietary CP concentration on weight gain. Broilers in T2 had lower ($P < 0.05$) feed intake than those in T1 and T3. Feed conversion in T2 and T4 was

similar ($P > 0.05$) and was better ($P < 0.05$) than that in T3. For the finisher phase (21-42 days), there was no effect ($P > 0.05$) of CP level on weight gain. Broilers in T3 had lower feed intake and better feed conversion than those in T1 ($P < 0.05$). Broilers in T2 and T4 showed intermediate values for these variables. Over the 42-day feeding period, there was no treatment effect ($P > 0.05$) on weight gain. Broilers in T1 had greater ($P < 0.05$) feed intake than those in T2 and T3, whereas broilers in T4 showed intermediate values. Broilers in T2 and T4 had better feed conversion ratios ($P < 0.05$) than those in T1; broilers in T3 showed intermediate values for this variable.

Carcass characteristics

Carcass characteristics of broiler chickens are shown in **Table 4**. There was no influence of treatment on weights of carcass, breast, drumsticks plus thighs, wings, or back fat ($P > 0.05$). Carcass yield was higher ($P < 0.05$) in T1 than T3. Chickens in T2 and T4 showed intermediate values. Likewise, there were no effects ($P > 0.05$) of dietary CP on the weights of liver, heart, or gizzard.

Table 3. Effect of protein concentration on the productive performance¹ of broilers chickens.

Tabla 3. Efecto de la concentración de proteínas en el rendimiento productivo¹ de pollos de engorde.

Variables and Feeding Stage	T1 ²	T2	T3	T4	P Value	SEM
Starter phase (1-21 days)						
Weight gain, g	920	909	898	948	0.30	19.6
Feed intake, g	1429a	1349b	1434a	1405ab	0.04	20.7
Feed conversion ratio ³	1.55ab	1.49b	1.60a	1.48b	0.03	0.03

Finisher phase (22-42 days)						
Weight gain, g	1919	1914	1918	1935	0.99	48.1
Feed intake, g	3980a	3820ab	3744b	3888ab	0.16	71.9
Feed conversion ratio	2.07a	1.99ab	1.96b	2.01ab	0.14	0.03
Entire study (1-42 days)						
Weight gain, g	2839	2823	2816	2883	0.84	55.9
Feed intake, g	5409a	5169b	5177b	5293ab	0.12	74.4
Feed conversion ratio ²	1.906a	1.832b	1.838ab	1.836b	0.10	0.02

¹Mean values (n = 5) with different letters in a row indicate significant difference (P < 0.05) between treatments (T).

²For starter and finisher diets crude protein (CP; %) levels were: 21.0 and 18.1 (T1); 21.4 and 18.5 (T2); 21.8 and 18.9 (T3); 22.2 and 19.3 (T4), respectively.

³Feed conversion ratio = feed intake, g/weight gain, g.

¹Valores de medias (n a 5) con letras diferentes en una fila indican diferencia significativa (P < 0.05) entre tratamientos (T).

²Para dietas de inicio y finalizado los niveles de proteína cruda (CP; %) fueron: 21.0 y 18.1 (T1); 21.4 y 18.5 (T2); 21.8 y 18.9 (T3); 22.2 y 19.3 (T4), respectivamente.

³Índice de conversión alimenticia = alimento consumido, g / aumento de peso, g.

Table 4. Broiler chicken carcass characteristics¹.

Tabla 4. Características de la canal de pollo de engorde¹.

Weights and carcass yield	T1 ²	T2	T3	T4	P Value	SEM
Live weight, g	3079	2950	2988	3169	0.36	91.6
Hot carcass weight, g	2337	2220	2214	2364	0.43	79.2
Breast weight, g/pair	894	866	839	923	0.53	41.2

Thigh + drumstick weight, g/pair	680	634	634	680	0.23	20.8
Wing weight, g/pair	230	215	219	231	0.21	6.3
Back weight, g	514	481	501	517	0.42	16.4
Abdominal fat weight, g	19.63	24.54	22.08	23.85	0.28	1.85
Liver weight, g	60.20	56.94	56.32	58.36	0.82	3.10
Heart weight, g	12.19	12.36	12.05	12.37	0.99	0.72
Gizzard weight, g	46.21	43.17	47.80	46.41	0.35	1.80
Carcass yield, % ³	75.90a	75.23ab	74.02b	74.56ab	0.15	0.57

¹Mean values (n = 5) with different letters in the row indicate significant differences (P < 0.05) between treatments (T).

²For starter and finisher diets crude protein (CP; %) levels were: 21.0 and 18.1 (T1); 21.4 and 18.5 (T2); 21.8 and 18.9 (T3); 22.2 and 19.3 (T4), respectively.

³Percentage of dressed carcass yield = (carcass weight, g)/live weight, g)*100.

¹Valores de medias (n a 5) con letras diferentes en una fila indican diferencia significativa (P < 0.05) entre tratamientos (T).

²Para dietas de inicio y finalizado los niveles de proteína cruda (CP; %) fueron: 21.0 y 18.1 (T1); 21.4 y 18.5 (T2); 21.8 y 18.9 (T3); 22.2 y 19.3 (T4), respectivamente.

³Porcentaje de rendimiento en canal = (Peso de canal, g / peso vivo, g)*100.

Proximate composition of meat

Results of the chemical composition of broiler chicken breast and thigh meat are shown in **Table 5**. Breast meat had similar (P > 0.05) percentages of water, ash, and ether extract; however, crude protein was greater (P < 0.05) in breast meat of birds in T2 than in T3. Chickens in T1 and T4 showed intermediate values. Thigh meat between treatments had similar (P > 0.05) water and ether extract percentages. Crude protein was highest (P < 0.05) for T2 and lowest (P < 0.05) for T3. With respect to ash, treatments T2 and T3 had higher values (P < 0.05) than in T1.

Table 5. Chemical composition (percentages) of broiler chicken breast and thigh muscles¹.

Tabla 5. Composición química (porcentajes) de los músculos de pechuga y muslo de pollo de engorde¹.

	T1 ²	T2	T3	T4	P	SEM
	Value					
Breast						
Water, %	75.12	74.74	74.62	74.33	0.46	0.43
Dry matter, %	24.88	25.26	25.38	25.67	0.46	0.34
Ash, %	5.61	5.64	6.14	6.52	0.22	0.34
Ether extract, %	4.50	4.60	4.78	5.35	0.63	0.49
Crude protein, %	90.91ab	92.63a	89.04b	90.84ab	0.04	0.78
Thigh						
Water, %	77.48	77.38	79.81	78.00	0.42	1.13
Dry matter, %	22.52	22.62	20.19	22.00	0.42	1.13
Ash, %	5.79b	6.61a	6.70a	6.38ab	0.05	0.23
Ether extract, %	10.81	10.35	9.84	10.48	0.73	0.61
Crude protein, %	86.12b	88.86a	78.95c	84.47b	<0.01	0.82

¹Mean values (n = 5) with different letters in the row indicate significant differences (P < 0.05) between treatments (T).

²For starter and finisher diets crude protein (CP; %) levels were: 21.0 and 18.1 (T1); 21.4 and 18.5 (T2); 21.8 and 18.9 (T3); 22.2 and 19.3 (T4), respectively.

¹Valores de medias (n a 5) con letras diferentes en una fila indican diferencia significativa (P < 0.05) entre tratamientos (T).

²Para dietas de inicio y finalizado los niveles de proteína cruda (CP; %) fueron: 21.0 y 18.1 (T1); 21.4 y 18.5 (T2); 21.8 y 18.9 (T3); 22.2 y 19.3 (T4), respectivamente.

Discussion

Growth performance

Both the starter and finisher diets had increasing crude protein levels from T1 to T4. Broiler weight gain was not influenced by the treatment; however, birds of T1 exhibited increased feed intake that negatively influenced feed conversion. Animals in T2, T3, and T4 showed roughly similar feed conversion ratios. Reports on productive performance of broiler chickens have been variable when comparing different levels of dietary crude protein. Houshmand *et al.* (2012) observed better growth performance of broiler fed diets containing 23.4% and 20.2% CP for starter and finisher diets, respectively, than birds fed the low protein diets. Abdel-Maksoud *et al.* (2010) reported maximum body weight and feed efficiency in starter broilers at 21% CP, particularly when supplemented with essential amino acids; broilers fed 19% and 23% CP diets showed lower productive parameters. Boonsinchai *et al.* (2016) observed no effect on growth performance in broilers (1-42 days) when dietary crude protein had a small reduction (5%) from the recommended requirement; however, reductions of 10% and 15% negatively affected feed efficiency.

Contrary to the observations of the present study, Ghazanfari *et al.* (2010) observed that in broilers that incremental changes in dietary protein levels did increase feed intake and improved weight gain and feed conversion, compared with a low level of protein in the diet. Jafarnejad *et al.* (2010) also reported improved weight gain and feed conversion in broilers (1-21 days) with high dietary protein levels (23% vs. 21% CP). Using mathematical models, Faridi *et al.* (2012) found that 24.1% dietary CP was the optimal level for feed efficiency in starter broilers. With a meta-analysis, Faridi *et al.* (2015) established 24.5% CP in the diet as the optimal level for feed efficiency for starter broilers 1-21 days of age. However, Laudadio *et al.* (2012a) reported that CP protein levels at 18.5%, 20.5%, and 22.5% did not affect growth performance of broilers during hot temperature conditions. In a three-week study with broiler chickens raised under a tropical hot and humid environment, Awad *et al.* (2014) observed reduced growth performance of broilers fed low-CP diets.

Improved productive performance of broiler chickens has been observed when increased over NRC recommendation the levels of lysine (Oliveira *et al.*, 2013; Bernal *et al.*, 2014; Quadros *et al.*, 2019; Zarghi *et al.*, 2020) and methionine plus cystine (Goulart *et al.*, 2011). In the current study, the increase in crude protein increased the lysine concentration in the diets over the NRC recommendations; however, the crude protein increase in diets did not have evident increase on the levels methionine plus cystine in the used diets over the NRC recommendations. It is possible that methionine plus cystine were not in the level required to optimize the productive performance of broiler chickens in the present study. The crude protein increase in diets was made by the increase in soybean meal that increased lysine; nevertheless, the increase in methionine plus cystine was less evident. Further research considering these adjust in amino acids should be made in this subtropical area of México, particularly in the summer when the average, maximum and minimum temperatures are 28 °C, 40 °C and 22 °C, respectively. Extra methionine supplementation has caused positive effects on health and antioxidant status of broiler chickens under heat stress (Liu *et al.*, 2019).

Carcass characteristics

In agreement with the results from the present study, Mandal *et al.* (2010) and Oliveira *et al.* (2013) reported that carcass characteristics and breast yields were not influenced by dietary CP level. Also, Miranda *et al.* (2015) did not report effects on carcass yield of broilers fed diets with different CP levels supplemented with L-valine and L-isoleucine; however, the proportion of abdominal fat was reduced without dietary supplementation of these amino acids.

Contrary to the information observed in the present study, Gheorghe *et al.* (2013a) observed greater carcass yields in broilers fed a diet with high vs. low protein levels. Gheorghe *et al.* (2013b) found that the increase in dietary protein did not affect carcass yield, but did improve breast and thigh yields and reduced abdominal fat. In agreement, Laudadio *et al.* (2012b) obtained higher muscle yields (breast and thigh) in broilers with a high protein diet than those with a medium protein or low protein diet. Likewise, Hada *et al.* (2013) and Dehghani and Jahanian (2016)

reported reduced carcass and breast yields using low protein diets; however, abdominal fat was increased with low protein diets.

Dozier III *et al.* (2008) recognized the importance of lysine in breast muscle formation; higher lysine levels than NRC recommendations promoted breast meat yield (Bernal *et al.*, 2014; Zarghi *et al.*, 2020). In the current study all diets were supplemented with the same lysine level and covered the NRC recommendation and the increase in CP level in diets had small increases in lysine or methionine plus cystine. Further research with higher levels of these amino acids in diets for broiler chickens to establish optimum productive efficiency and carcass yield is necessary in the dry subtropics of Mexico.

Proximate composition of meat

Contrary to the observations from the present study, increased dietary protein levels in other studies boosted protein and reduced lipid deposition in broiler chicken muscle (Marcu *et al.*, 2012; Marcu *et al.*, 2013). Nagata *et al.* (2011) reported that high dietary energy also requires adequate CP to ensure protein deposition in the muscles of birds. In contrast, Gómez *et al.* (2011) found no effect of dietary CP on carcass protein deposition, although low crude protein diets were supplemented with amino acids that were used for muscles growth in the birds.

Conclusions

In the present study, conducted in a subtropical area of northeastern Mexico, in the entire study (1-42 d) broiler chickens fed 21.4% and 18.5% CP (T2) in starter and finisher diets, respectively, had better feed conversion ratio than broilers fed the lower CP diet (21.0% and 18.1% (T1), respectively). Increases in CP over T2 did not improve broiler feed conversion ratio. Carcass

characteristics showed minimal influences of dietary CP level; however, crude protein concentration in thigh was optimal in T2.

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References

- AOAC. (1990). *Official methods of analysis*, 15th ed. Association of Official Analytical Chemists, Arlington
- Abdel-Maksoud, A., Yan, F., Cerrate, S., Coto, C., Wang, Z., & Waldroup, P. W. (2010). Effect of dietary crude protein, lysine level and amino acid balance on performance of broilers 0 to 18 days of age. *International Journal of Poultry Science*, 9(1), 21-27. DOI: 10.3923/ijps.2010.21.27
- Aftab, U. (2019). Energy and amino acid requirements of broiler chickens: keeping pace with the genetic progress. *World's Poultry Science Journal*, 75(4), 507-514. DOI: <https://doi.org/10.1017/S0043933919000564>
- Amiri, M., Ghasemi, H. A., Hajkhodadadi, I., & Farahani, A. H. K. (2019). Efficacy of guanidinoacetic acid at different dietary crude protein levels on growth performance, stress indicators, antioxidant status, and intestinal morphology in broiler chickens subjected to cyclic heat stress. *Animal Feed Science and Technology*, 254,114208. DOI: <https://doi.org/10.1016/j.anifeedsci.2019.114208>
- Applegate, T. J., & Angel, R. (2014). Nutrient requirements of poultry publication: History and need for an update. *Journal of Applied Poultry Research*, 23(3), 567-575. DOI: <https://doi.org/10.3382/japr.2014-00980>
- Awad, E. A., Zulkifli, I., Farjam, A. S., & Chwen, L. T. (2014). Amino acids fortification of low-protein diet for broilers under tropical climate. 2. Nonessential amino acids and increasing essential amino acids. *Italian Journal of Animal Science*, 13(2), 270-274. DOI: 10.4081/ijas.2014.3166

- Bernal, L. E. P., Tavernari, F. C., Rostagno, H. S., & Albino, L. F. T. (2014). Digestible lysine requirements of broilers. *Brazilian Journal of Poultry Science*, 16(1), 49-55. DOI: <http://dx.doi.org/10.1590/S1516-635X2014000100007>.
- Boonsinchai, N., Potchanakorn, M., & Kijparkorn, S. (2016). Effects of protein reduction and substitution of cassava for corn in broiler diets on growth performance, ileal protein digestibility and nitrogen excretion in feces. *Animal Feed Science and Technology*, 216, 185-196. DOI:<https://doi.org/10.1016/j.anifeedsci.2016.03.022>
- Dehghani-Tafti, N., & Jahanian, R. (2016). Effect of supplemental organic acids on performance, carcass characteristics, and serum biochemical metabolites in broilers fed diets containing different crude protein levels. *Animal Feed Science and Technology*, 211, 109-116. <https://doi.org/10.1016/j.anifeedsci.2015.09.019>
- Dozier III, W. A., Kidd, M. T., & Corzo A. 2008. Dietary amino acid responses of broiler chickens. *Journal of Applied Poultry Research*, 17(1), 157-167. DOI: <https://doi.org/10.3382/japr.2007-00071>
- Faridi, A., Golian, A., & Ahmadi, H. (2012). Comparison of responses to dietary protein and lysine in broiler chicks reared before and after 2000 via neural network models. *The Journal of Agricultural Science*, 150(6), 775-786. DOI: <https://doi.org/10.1017/S0021859612000305>
- Faridi, A., Gitoee, A., & France J. (2015). Evaluation of the effects of crude protein and lysine on the growth performance of two commercial strains of broilers using meta-analysis. *Livestock Science*, 181, 77-84. DOI: <https://doi.org/10.1016/j.livsci.2015.10.010>
- Ghazanfari, S., Tahmoorespur, M., & Nobari, K. (2010). Changes in ghrelin mRNA level, plasma growth hormone concentration and performance in different dietary energy and protein levels in broiler chicken. *Italian Journal of Animal Science*, 9(e56), 290-295. DOI: <https://doi.org/10.4081/ijas.2010.e56>
- Gheorghe, A., Dragotoiu, D., Ciurescu, G., Lefter, N., & Hăbeanu, M. (2013a). Effects of dietary protein level on protein deposition in broilers: 2. Body composition, plasma metabolic profile and litter composition. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. *Animal Science and Biotechnologies*, 70(2), 274-283. DOI: <http://dx.doi.org/10.15835/buasvmcn-asb:70:2:9303>
- Gheorghe, A., Dragotoiu, D., Ciurescu, G., Lefter, N., & Hăbeanu, M. (2013b). Effects of dietary protein level on protein deposition in broilers: 1. Productive performance and carcass

characteristics. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Animal Science and Biotechnologies*, 70(2), 266-273. DOI: <http://dx.doi.org/10.15835/buasvmcn-asb:70:2:9253>

Gómez, R. S., Cortés Cuevas, A., López Coello, C., & Ávila González, E. (2011). Evaluación de tres programas de alimentación para pollos de engorda con base en dietas sorgo-soya con distintos porcentajes de proteína. *Veterinaria México*, 42(4), 299-309. <http://www.scielo.org.mx/pdf/vetmex/v42n4/v42n4a5.pdf>

Goulart, C.C., Costa, F.G.P., Silva, J.H.V., Souza, J.G., Rodrigues, V.P., & Oliveira, C.F.S. (2011). Requirements of digestible methionine + cystine for broiler chickens at 1 to 42 days of age. *Revista Brasileira de Zootecnia*, 40(4), 797-803. DOI: <https://doi.org/10.1590/S1516-35982011000400013>

Hada, F. H., Malheiros, R. D., Silva, J. D. T., Marques, R. H., Gravena, R. A., Silva, V. K., & Moraes, V. M. B. (2013). Effect of protein, carbohydrate, lipid, and selenium levels on the performance, carcass yield, and blood changes in broilers. *Brazilian Journal of Poultry Science*, 15(4), 385-394. DOI: <http://dx.doi.org/10.1590/S1516-635X2013000400014>

Houshmand, M., Azhar, K., Zulkifli, I., Bejo, M. H., & Kamyab, A. (2012). Effects of non-antibiotic feed additives on performance, immunity and intestinal morphology of broilers fed different levels of protein. *South African Journal of Animal Science*, 42(1), 23-32. DOI: <http://dx.doi.org/10.4314/sajas.v42i1.3>

Jafarnejad, S., Farkhoy, M., Sadegh, M., & Bahonar, A. R. (2010). Effect of crumble-pellet and mash diets with different levels of dietary protein and energy on the performance of broilers at the end of the third week. *Veterinary Medicine International*, 2010: p1-5. DOI: <https://doi.org/10.4061/2010/328123>

INEGI. Instituto Nacional de Estadística, Geografía e Informática. (2017). Anuario Estadístico del Estado de Tamaulipas. Accessed 16 January 2020. http://www.datatur.sectur.gob.mx/itxef_docs/tams_anuario_pdf.pdf

Laudadio, V., Dambrosio, A., Normanno, G., Khan, R. U., Naz, S., Rowghani, E., & Tufarelli, V. (2012a). Effect of reducing dietary protein level on performance responses and some microbiological aspects of broiler chickens under summer environmental conditions. *Avian Biology Research*, 5(2), 88-92. DOI:<https://doi.org/10.3184/175815512X13350180713553>

- Laudadio, V., Passantino, L., Perillo, A., Lopresti, G., Passantino, A., Khan, R. U., & Tufarelli, V. (2012b). Productive performance and histological features of intestinal mucosa of broiler chickens fed different dietary protein levels. *Poultry Science*, *91*(1), 265-270. DOI: 10.3382/ps.2011-01675.
- Liu, G., Magnuson, A. D., Sun, T., Tolba, S. A., Starkey, C., Whelan, R., & Lei, X. G. (2019). Supplemental methionine exerted chemical form-dependent effects on antioxidant status, inflammation-related gene expression, and fatty acid profiles of broiler chicks raised at high ambient temperature. *Journal of animal science*, *97*(12), 4883–4894. DOI: <https://doi.org/10.1093/jas/skz348>
- Mandal, A. B., Panda, A. K., Elangovan, A. V., Deo, C., & Shrivastav, H. P. (2010). Effect of different dietary protein levels supplemented with limiting amino acids on the performance of broilers in extreme summer. *Indian Journal of Poultry Science*, *45*(3), 283-286. <https://www.indianjournals.com/ijor.aspx?target=ijor:ijps&volume=45&issue=3&article=009>
- Marcu, A., Vacaru-Opriș, I., Marcu, A., Nicula, M., Dronca, D., & Kelciiov, B. (2012). The Influence of Feed Energy and Protein Level on Meat Quality at „Hubbard F15“ Broiler Chickens. *Animal Science and Biotechnologies*, *45*(2), 432-439. <https://www.spasb.ro/index.php/spasb/article/view/422>
- Marcu, A., Vacaru-Opriș, I., Dumitrescu, G., Petculescu, C., Marcu, A., Petculescu-Ciochină, L., Nicula, M., Dronca, D., & Kelciiov, B. (2013). Effect of Diets with Different Energy and Protein Levels on Breast Muscle Characteristics of Broiler Chickens. *Animal Science and Biotechnologies*, *46*(1), 333-340. <http://spasb.ro/index.php/spasb/article/view/229>
- Miranda, D. J. A., Vieira, S. L., Favero, A., Angel, C. R., Stefanello, C., & Nogueira, E. T. (2015). Performance and meat production of broiler chickens fed diets formulated at different crude protein levels supplemented or not with L-valine and L-isoleucine. *Animal Feed Science and Technology*, *206*, 39-47. DOI: <https://doi.org/10.1016/j.anifeedsci.2015.04.018>
- Nagata, A. K., Rodrigues, P. B., Alvarenga, R. R., Zangeronimo, M. G., Donato, D. C. Z., & Silva, J. H. V. D. (2011). Carcass characteristics of broilers at 42 days receiving diets with phytase in different energy and crude protein levels. *Ciência e Agrotecnologia*, *35*(3), 575-581. DOI: <https://doi.org/10.1590/S1413-70542011000300020>.

- National Research Council (NRC). 1994. Nutrient requirements of poultry, 9th ed. National Academy Press, Washington
- Oliveira, W. P. D., Oliveira, R. F. M. D., Donzele, J. L., Oliveira Neto, A. R. D., Gomes, P. C., Maia, A. P. D. A., Campos, P. H. R. S., & Gasparino, E. (2013). Dietary crude protein reduction on growth and carcass performance of 22 to 42-day-old broilers reared under different temperatures. *Revista Brasileira de Zootecnia*, 42(8), 599-604. DOI: <http://dx.doi.org/10.1590/S1516-35982013000800010>
- Quadros, T. O., Duarte, K. F., Sgavioli, S., Alva, J. C. R., Domingues, C. H., Santos, E. T., Castiblanco, D. M. C., Marques, R. H., Amoroso, L., & Junqueira, O. M. (2019). Digestible lysine supplementation influences weight gain in 21-day-old broiler chickens. *Archivos de Zootecnia*, 68(261), 120-126. DOI: <https://doi.org/10.21071/az.v68i261.3947>
- SAS. (2002). *SSAS/STAT User's Guide* (Release 9.2). Cary, NC: Author.
- UNA. 2019. Unión Nacional de Avicultores. <https://www.una.org.mx/indicadores-economicos/>. Accessed on January of 2020.
- Zarghi, H., Golian, A., & Nikbakhtzade, M. (2020). Effect of dietary digestible lysine level on growth performance, blood metabolites and meat quality of broilers 23–38 days of age. *Journal of Animal Physiology and Animal Nutrition*, 104(1), 156-165. DOI: <https://doi.org/10.1111/jpn.13214>
- Zulkifli, I., Akmal, A. F., Soleimani, A. F., Hossain, M. A., & Awad, E. A. (2018). Effects of low-protein diets on acute phase proteins and heat shock protein 70 responses, and growth performance in broiler chickens under heat stress condition. *Poultry Science*, 97(4), 1306–1314. DOI: 10.3382/ps/pex436.