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Revista Colombiana de Ciencias Pecuarias

Original Research Articles

Effect of feeding carrot flour on performance and profitability of broilers

Efecto de la alimentación con harina de zanahoria sobre el rendimiento y rentabilidad de los pollos de engorde

Efeito da alimentação com farinha de cenoura no desempenho e lucratividade de frangos de corte

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To cite this article:
Jácome-Gómez J, Loor-Moreira G, De-la-Cruz-Chicaiza M, Intriago-Vera J, Espinoza-Zambrano J, Milton Zambrano-Rivera. Effect of feeding carrot flour on performance and profitability of broilers. Rev Colomb Cienc Pecu. 2025; 38(2):e3828. DOI: https://doi.org/10.17533/udea.rccp.v38n2a8

Received: February 6, 2024.
Accepted: November 7, 2024.

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Abstract

Background: The quality of chicken meat, essential for consumer satisfaction, is influenced by skin pigmentation. The lack of carotenoids in conventional diets has driven the search for cost-effective alternatives to enhance these aspects in poultry production. **Objective:** This study assessed the impact of partially replacing commercial balanced feed with different levels of carrot flour (*Daucus carota* subsp. *sativus*) on productive parameters and the pigmentation of broiler chickens. **Methods:** Sixty-four Cobb 500 birds were randomly assigned to four experimental diets, each with eight replicates of two birds. The control group (T0) received a standard diet, while the experimental groups received a diet with 10% (T1), 15% (T2), and 20% (T3) replacement with carrot flour (CF). Variables such as feed consumption, weight gain, feed conversion, mortality, skin pigmentation, and profitability were evaluated. **Results:** Treatments with 15% and 20% CF resulted in significantly higher feed consumption ($p < 0.05$) compared to the control group. Although weight gain did not show significant differences between groups ($p > 0.05$), a trend towards higher gains was observed in the experimental groups. The feed conversion ratio increased non-significantly ($p > 0.05$) with higher CF concentrations. No mortality was observed in the experimental groups, whereas the control group had a mortality rate of 12.5%. Regarding pigmentation, CF influenced skin color as its concentration in the diet increased. In terms of profitability, the 15% replacement treatment stood out by generating higher income and a superior cost-benefit ratio. **Conclusion:** Orange cultivar CF can be a viable dietary source of natural pigment for broiler chickens. It may also be beneficial in promoting weight gain and reducing mortality, translating into economic advantages.

Keywords: *Carotenoids; carrot; chicken feed; meat quality; natural pigment; profitability; skin color; yellow-skinned chicken.*

Resumen

Antecedentes: La calidad de la carne de pollo, esencial para la satisfacción del consumidor, se ve influida por la pigmentación de la piel. La falta de carotenoides en las dietas convencionales ha impulsado la búsqueda de alternativas rentables para mejorar estos aspectos en la producción avícola. **Objetivo:** Este estudio evaluó el efecto de la sustitución parcial del alimento balanceado comercial con diferentes niveles de harina de zanahoria (*Daucus carota* subsp. *sativus*) sobre los parámetros productivos y la pigmentación de los pollos de engorde. **Métodos:** Sesenta y cuatro aves Cobb 500 fueron asignadas aleatoriamente a cuatro dietas experimentales, con ocho repeticiones de dos aves cada una. El grupo control (T0) recibió una dieta estándar, mientras que los grupos experimentales recibieron una dieta con 10% (T1), 15% (T2) y 20% (T3) de reemplazo del alimento balanceado por harina de zanahoria (HZ). Se evaluaron las variables consumo de alimento, ganancia de peso, conversión alimenticia, mortalidad, pigmentación de la piel y rentabilidad. **Resultados:** Los tratamientos con 15% y 20% de HZ resultaron en un consumo de alimento significativamente mayor ($p < 0.05$) en comparación con el grupo control. Aunque la ganancia de peso no mostró diferencias significativas entre los grupos ($p > 0.05$), se observó una tendencia hacia mayores ganancias en los grupos con HZ. El índice de conversión alimenticia mostró un incremento no significativo ($p > 0.05$) con mayores concentraciones de HZ. Ninguno de los grupos experimentales presentó mortalidad, mientras que el grupo control tuvo una tasa de mortalidad del 12.5%. En cuanto a la pigmentación, la HZ influyó en la coloración de la piel a medida que aumentaba su concentración en la dieta. En relación con la rentabilidad, destacó el tratamiento con el 15% de reemplazo, que generó mayores ingresos y un índice superior de beneficio/costo. **Conclusión:** La HZ del cultivar anaranjado puede ser una fuente dietética viable de pigmento natural para pollos de engorde. Además, puede favorecer la ganancia de peso y reducir la mortalidad, lo que se traduce en beneficios económicos.

Palabras clave: *Alimento para pollos; calidad de la carne; carotenoides; color de piel; pigmento natural; pollo de piel amarilla; zanahoria; rentabilidad.*

Resumo

Antecedentes: A qualidade da carne de frango, essencial para a satisfação do consumidor, é influenciada pela pigmentação da pele. A falta de carotenoides nas dietas convencionais tem impulsionado a busca por alternativas rentáveis para aprimorar esses aspectos na produção avícola. **Objetivo:** Este estudo avaliou o efeito da substituição parcial da ração comercial por diferentes níveis de farinha de cenoura (*Daucus carota* subsp. *sativus*) sobre os parâmetros produtivos e a pigmentação de frangos de corte. **Métodos:** Sessenta e quatro aves da linhagem Cobb 500 foram aleatoriamente designadas a quatro dietas experimentais, com oito réplicas de duas aves cada. O grupo controle (T0) recebeu uma dieta padrão, e os grupos experimentais receberam uma dieta com 10% (T1), 15% (T2) e 20% (T3) de substituição da ração por farinha de cenoura (FC). Foram avaliadas as variáveis consumo de ração, ganho de peso, conversão alimentar, mortalidade, pigmentação da pele e rentabilidade. **Resultados:** Os tratamentos com 15% e 20% de FC resultaram em um consumo de ração significativamente maior ($p < 0{,}05$) em comparação com o grupo controle. Embora o ganho de peso não tenha mostrado diferenças significativas entre os grupos ($p > 0{,}05$), observou-se uma tendência de maiores ganhos nos grupos experimentais. O índice de conversão alimentar aumentou de forma não significativa ($p > 0{,}05$) com concentrações mais altas de FC. Nenhum dos grupos experimentais apresentou mortalidade, enquanto o grupo controle teve uma taxa de mortalidade de 12,5%. Quanto à pigmentação, a FC influenciou a coloração da pele conforme aumentava sua concentração na dieta. Em relação à rentabilidade, o tratamento com 15% de substituição destacou-se ao gerar maiores receitas e uma relação benefício/custo superior. **Conclusão:** A FC do cultivar alaranjado pode ser uma fonte dietética viável de pigmento natural para frangos de corte. Além disso, pode favorecer o ganho de peso e reduzir a mortalidade, resultando em benefícios econômicos.

Palavras-chave: *carotenoides; cenoura; cor da pele; frango de pele amarela; lucratividade; pigmento natural; qualidade da carne.*

Introduction

Meat quality is a fundamental aspect of poultry production and plays a crucial role in marketing due to its close connection to consumer satisfaction (Baéza et al., 2022). High-quality meat encompasses sensory and nutritional properties. However, nutritional indicators cannot be assessed before consumption. Consumers tend to rely on sensory signals to predict food quality (de Araújo et al., 2022). Among these signals, skin pigmentation stands out as the most important attribute associated with freshness and is perceived as an indicator of safe food (Qamar, 2019). Although pigmentation does not, in practical terms, guarantee food safety, its influence on the initial judgment of meat affects purchasing decisions, making it an important economic trait (de Araújo et al., 2022).

In Ecuador, there is a preference for a yellow skin color (Toalombo et al., 2019). However, the main broiler chicken breeds lack the genetic capacity to naturally develop the appropriate color intensity (Wu et al., 2021). As a result, poultry producers often add synthetic or natural pigments to the ingredients used to enhance the pigmentation of yellow-skinned chickens (Rana et al., 2021). However, synthetic pigments raise health and bioavailability concerns, while natural pigments are often unviable due to their high costs (Martínez-Cámara et al., 2021). These limitations have led to a growing interest in the search for natural sources rich in carotenoids that are cost-effective for inclusion in bird diets (Pasarin & Rovinaru, 2018).

Previous studies (Dabai et al., 2021; Khan et al., 2019; Ng'Ambi et al., 2019; Muzaki et al., 2017; Ürüşan et al., 2018) have documented the potential of carrots to improve meat quality in Hubbard, Lohmann, and Arbor Acre chickens. Additionally, these studies observed significant improvements in productive performance. However, they did not specify the carrot subspecies used. This lack of specificity complicates the understanding of how different carrot subspecies could influence the observed results, as carrot (*Daucus carota* L.) is known for its richness in carotenoids, and the total content of these compounds varies according to the root color. Among these, orange cultivars stand out for having up to ten times higher carotenoid content (Perrin et al., 2017).

It is crucial to determine which carrot subspecies yields the desired effects in terms of pigmentation and bird performance to develop more effective and replicable feeding strategies. Additionally, to the best of our knowledge, no studies have been conducted on the impact of carrots on the meat quality of Cobb 500 chickens, suggesting the need for research on this genetic line before generalizing the observed benefits from other studies.

Thus, the main objective of this study was to evaluate the effect of carrot flour (*Daucus carota* subsp. *sativus*) on the pigmentation, productive parameters, and profitability of Cobb 500 broiler chickens.

Materials and Methods

Ethical considerations

This study received approval from the Research Ethics Committee of Universidad Laica Eloy Alfaro de Manabí. It complies with the ethical regulations established for scientific research processes involving animals at the institution (RCU-SE-No.47-2016), which focus on ensuring the animals' quality of life, providing suitable conditions for transportation and housing, and avoiding excessive handling that may cause suffering. The sacrifice process was conducted following the protocol established by the Agencia de Regulación y Control Fito y Zoosanitario de Ecuador (AGROCALIDAD, 2023).

Experiment location

The study was conducted at the Río Suma Experimental Farm, located at the Faculty of Agricultural Engineering of Universidad Laica Eloy Alfaro de Manabí, El Carmen extension, Manabí province, Ecuador. The georeferential coordinates are -0.262655 S and -79.427579 W, in an area characterized by a humid tropical climate. The agroecological conditions in this area include an altitude of 260 m above sea level, an air temperature in the shade of 24°C, an average annual precipitation of 190.98 mm, a relative humidity of 86%, with 1,026 hours of sunlight exposure per year, and an annual evaporation of 1,064 mm (INAMHI, 2019).

Experimental design

A total of 64 Cobb 500 broiler chickens were randomly assigned to three experimental diets and one control diet, with eight replicates of two birds each. The treatments involved the partial substitution of commercial balanced feed with three levels of carrot flour (Table 1).

Table 1. Experimental diets.

Dietary Components	T0	T1	T2	T3
Commercial balanced feed (CBF)	100%	90%	85%	80%
Carrot flour (CF)	-	10%	15%	20%

Carrot flour

Rejected orange-colored carrot roots (*Daucus carota* subsp. *sativus)* with aesthetic defects were purchased from a local producer in Ambato canton, Tungurahua, Ecuador. Following the method of Hernández et al. (2015), the carrots were washed with 0.1% chlorinated water and cut into ~2 mm thick slices using a vegetable cutter (Sirman, model TM2 INOX). They were then dried at 60°C for 20 hours in a dehydrator (Vikale model MQ-DH-10). Subsequently, the dried carrots were ground using a manual mill (Victoria, model 30018), yielding 13.50%.

The nutritional values of the balanced feed used in diet formulation were obtained from the food composition table. To determine the nutritional composition of carrot flour, a sample was sent to the laboratory for bromatological analysis (Table 2). The total carotenoid content was determined by spectrophotometry at 450 nm (UV-VIS Spectrophotometer Model T6U-UV-VIS), with a result of 21.34 mg/100 g.

Table 2. Nutritional composition of commercial balanced feed and carrot flour (per 100 g).

Parameter	Balanced Feed	Carrot Flour	Method
(%) Moisture	13	9.2	AOAC, Ed. 21. 2019 934.01
(% DM) Protein	18	8.92	AOAC, Ed. 21. 2019 2001.11
(% DM) Crude Fat	5	1.34	AOAC, Ed. 21. 2019 920.39
(% DM) Ash	7	5.78	AOAC, Ed. 21. 2019 942.05
(% DM) Fiber	4	7.84	ISO 16472-2007

The formulated diets were neither isoproteic nor isoenergetic. Although no analysis was conducted on the dilution effect of the nutrients, it was estimated that the protein content varied, with values of 18% in T0, 17.1% in T1, 16.6% in T2, and 16.2% in T3, reflecting a reduction of 5% to 10%. Considering that the optimal protein range for Cobb 500 chickens is between 17% and 18% (Cobb-Vantress, 2018), the diets that included carrot flour remained within an acceptable range.

Experimental management

The birds, acquired at five days old with an initial weight of 45 g, were housed in a brooding circle until day 10. Subsequently, they were randomly distributed into experimental units. During the first 21 days, they were provided with the same standard diet formulated to meet nutritional requirements at each stage. From then on until they reached the target weight on day 39, they received commercial balanced feed with carrot flour according to the substitution levels. This represented a total experimental feeding period of 17 days. All birds were immunized against Newcastle disease, infectious bronchitis, and Gumboro disease. Additionally, they had free access to clean water and feed.

Evaluation methodology

Throughout the 39 days the birds were kept in the poultry house, a daily record of food consumption was maintained, subtracting rejected food from the total provided. Weekly weight measurements were taken, and health status and mortality were monitored daily. Weighing was conducted at 7:00 a.m., prior to feeding. Subsequently, during the evaluation phase, the following productive parameters were calculated and analyzed for each treatment:

Cumulative Feed Consumption (g/bird): Estimated as the total amount of food consumed divided by the number of birds fed.

Cumulative Weight Gain (g/bird): Calculated as the final weight minus the initial weight.

Feed Conversion Ratio (FCR): Determined by dividing total food consumed by weight gained. A lower FCR indicates higher efficiency in feed conversion.

Mortality rate (%): Determined as the number of deceased birds divided by the initial bird count.

Pigmentation: On day 39, birds were sacrificed using the bleeding method, manually cutting the carotid arteries. Subsequently, scalding at 54°C for 4 minutes and feather removal were performed, preserving skin integrity. Skin pigmentation was evaluated post-evisceration, including control group birds. Color intensity was measured using a Roche colorimetric fan, which ranges from 1 (nearly white) to 16 (dark tomato), with intermediate yellow and tomato gradations.

Profitability: Estimated using the benefit/cost (B/C) ratio:

B/C Ratio = (Income/Costs)×100

Only feeding and vaccination costs were considered, along with income from meat sales based on weight. A B/C ratio > 1 indicates profitability.

Statistical analysis

The data were analyzed using analysis of variance (ANOVA) and presented as mean values. To ensure ANOVA validity, normality was assessed using the Shapiro-Wilk test, confirming the normality assumptions. Mean comparisons were performed using the Tukey test, with a significance level of $p < 0.05$. All analyses were conducted using Infostat® statistical software, version 2020.

Results

Productive parameters

As detailed in Table 3, chickens that received a diet composed of 90% CBF and 10% carrot flour (T1) and those that received a diet composed of 85% CBF and 15% carrot flour (T2) showed similar feed consumption, which was significantly higher ($p < 0.05$) compared to the control group (T0). However, weight gain did not reach statistical significance ($p > 0.05$); nevertheless, it was observed that the experimental groups, particularly chickens in treatment T3, exhibited greater numerical weight gain than the control group (T0). Regarding the feed conversion ratio, it was observed that as the level of substitution with carrot flour increased, chickens showed a non-significant increase ($p > 0.05$) in conversion values, with variability among experimental groups. The best feed conversion ratio was observed in the control group, followed by chickens in treatment T3. Regarding mortality, no losses were recorded in the groups of chickens that received diets with carrot flour. In contrast, the control group had a total of 2 deaths, equivalent to a mortality rate of 12.5%.

Table 3. Statistical comparison of productive parameters.

Parameters	T0	T1	T2	T3
Cumulative feed consumption CBF + CF (g/bird)	3850.97[a]	4178.53[ab]	4323.41[b]	4350.35[b]
Cumulative weight gain (g/bird)	2489.69[a]	2555.13[a]	2704.06[a]	2780.94[a]
Feed conversion ratio CBF + CF	1.55[a]	1.64[a]	1.60[a]	1.56[a]
Mortality rate (%)	12.5	0.00	0.00	0.00

Means with a common letter are not significantly different ($p > 0.05$); **CBF:** Commercial balanced feed; **CF:** Carrot flour.

Pigmentation

As observed in Table 4, increasing the concentration of carrot flour (*Daucus carota* subsp. *sativus*) resulted in progressively more intense pigmentation. The treatment with 10% carrot flour (T1) achieved light pigmentation with a slight hint of yellow, while the treatment with 15% (T2) exhibited a pale-yellow color intensity. Likewise, the treatment with 20% carrot flour (T3) showed a more intense and defined yellow hue. In contrast, the control group (T0) exhibited very minimal pigmentation, leaning towards a white tone.

Table 4. Comparison of skin pigmentation variability in broiler chickens.

Pigmentation	T0	T1	T2	T3
Average color Intensity (Scale: 1-16)	0.50	2.25	4.00	5.75

Profitability

Table 5 presents data related to the profitability analysis of each treatment. Regarding revenue, treatment T2 recorded the highest figure, followed by treatment T3, T1, and T0. Treatment T3 exhibited the highest cost, followed by T2, T1, and T0. Similarly, all treatments show B/C values above 1, indicating that they generate revenues surpassing associated costs, i.e., they are profitable. However, treatment T0 (control group) had the lowest B/C value. Overall, treatment T2 stood out for recording the highest revenue and a greater B/C ratio compared to the other treatments.

Table 5. Economic analysis.

Metrics	T0	T1	T2	T3
Income (USD)	96,40	116,92	123,74	118,10
Costs (USD)	61,50	71,88	73,80	74,15
B/C (USD)	1,57	1,63	1,68	1,59

B/C: Benefit-Cost Ratio; **USD:** United States Dollar.

Discussion

Our results indicate that partial substitution of balanced feed with carrot flour (*Daucus carota* subsp. *sativus*) in the diet of Cobb 500 broilers increases feed intake and improves weight gain. These findings align with previous research by Ng'Ambi et al. (2019) and Noviadi & Maradon (2021), which also found positive effects on feeding behavior and weight gain when supplementing the Arbor Acre chicken diet with carrot flour.

According to Forbes (2010), in farm animals, increased feed consumption of a particular diet compared to another can be attributed to its attractiveness in terms of palatability. In this regard, the chickens' response to feed intake may be related to the palatability of the diet, driven by taste, texture, and the availability of nutrients such as carotenoids, vitamins, and minerals in carrot flour that stimulate consumption (Murugesan et al., 2021; Yunitasari et al., 2023).

Given that chickens consumed more feed when including carrot flour in their diet, they could have ingested more calories overall, leading to greater weight gain (Silondae et al., 2023). However, the improvement in body weight was accompanied by a decrease in feed conversion efficiency. This coincides with the results of Muzaki et al. (2017), who observed that the inclusion of carrot waste flour in the diet of Lohmann chickens proportionally affected feed conversion efficiency.

As noted by Jha & Mishra (2021), one cause of this adverse effect on feed efficiency could be the fiber content in the diet. The author suggests that a diet with a high fiber content can reduce the digestibility of feed, so absorbed nutrients also decrease. Therefore, the problem in utilizing the CBF + CF mixture could be related to the increased fiber content, which is estimated at 7.84% in the carrot flour portion.

However, the variability in feed conversion efficiency among experimental groups suggests that while the chickens may have shown better adaptation or tolerance to the 10% carrot flour substitution level, other factors, such as the interaction between diet nutrients, the physiological response of chickens to different ingredient proportions, and the management and maintenance parameters of each treatment, could have influenced these results (Baracho et al., 2019; Jácome-Gómez et al., 2022).

The results of the productive parameters indicate that the reduction in protein intake did not have an adverse effect on the chickens' growth. This finding could be attributed to several factors, among which the ability of Cobb 500 chickens to adapt to diets with a lower amino acid density without compromising their performance stands out (Cobb-Vantress, 2018). Previous research has shown that Cobb 500 broilers can benefit from diets that do not necessarily meet the highest protein content, as long as other nutrients are available in adequate quantities and are highly digestible (Woyengo et al., 2023). Additionally, it is plausible that the increased feed intake allowed the chickens to reach the total nutrient intake necessary to sustain their growth and development, thus compensating for the reduction in dietary protein. However, further research is needed to confirm these results and understand why broiler chickens can maintain growth despite the reduction in protein content in their diets. Identifying the specific factors that enable this adaptation could further optimize dietary formulations and improve feed efficiency without compromising productive performance.

On the other hand, regarding mortality, in chickens fed diets that included carrot flour, no deaths were recorded, whereas the control group had a total of two deaths. This observation is supported by Silondae et al. (2023), who did not detect mortality in chickens fed diets containing carrots. According to Khan et al. (2023) and Nabi et al. (2020), carrots, due to their antioxidant and carotenoid content, could provide cellular protection to chickens by reducing oxidative stress and improving overall health. However, it is important to consider that other factors, such as management conditions, water quality, and overall chicken nutrition, could also have influenced the observed results, so further studies are needed to confirm this potential effect and determine the specific contribution of carrot flour to bird health.

Additionally, the results indicate that the carotenoids present in carrot flour (*Daucus carota* subsp. *sativus*) have the potential to positively influence the skin coloration of broiler chickens. This aligns with the report by Wang et al. (2023), suggesting that poultry skin pigmentation is related to the intake of carotenoid pigments from their diet. However, it is important to note that not all studies have reached the same conclusions, such as the work of Azizah et al. (2017), which found no observable effects on the pigmentation of Lohmann broiler chickens when including carrot waste flour in their diets. Differences may be attributed to variability in the amount of carotenoids obtained from carrot waste and their level of incorporation into the supplied diet. Additionally, the study does not specify which carrot subspecies was used.

Regarding profitability, while we did not observe a substantial reduction in feeding costs, the average income per kg of chicken meat was USD 0.63, representing a 10% increase compared to conventionally fed chicken meat (USD 0.57). This indicates that using carrot flour as a substitute in the diet of broiler chickens can provide greater economic benefits. These results are particularly interesting as there are few studies specifically addressing profitability in relation to the use of carrots as a source of carotenoids in poultry feeding. The study by Chamba-Ochoa et al. (2020) is one of the few documented cases, and our results surpass their findings in terms of an increase in the cost-benefit ratio.

In summary, this study provides preliminary evidence of the potential benefits of incorporating carrot (*Daucus carota* subsp. *sativus*) in the rearing of Cobb 500 broiler chickens. These benefits are reflected in both productive performance and economic profitability, presenting a viable alternative to reduce or eliminate the need for artificial pigments in poultry production. These findings are valuable for the feed industry and contribute to decision-making in formulating diets to produce yellow-skinned chickens.

Nevertheless, further research is necessary to delve into the influence of key variables, such as the specific quantity and quality of carrot used in the birds' diet. Additionally, more detailed studies should increase the number of experimental units to enhance statistical power and reliability. It is also important to consider the sex of the birds as a potential source of variation, given its possible influence on performance and pigmentation outcomes. Moreover, experimental conditions—such as environment, genetics, and management- can significantly affect the results. Therefore, generalizing these findings is premature. Further studies are needed to better understand the effects of carrot flour inclusion on performance and skin pigmentation to optimize nutritional strategies for yellow-skinned broiler production.

Declarations

Conflicts of interest

The authors declare they have no conflicts of interest regarding the work presented in this report.

Authors' contributions

JJG: Study design, project administration, data collection, manuscript review, and writing. MDLC: Data processing, formal analysis, interpretation of data, and manuscript writing. JEZ and GLM: Methodology, preparation of carrot meal, bromatological analysis, and manuscript writing. MZR and JIV - Conceptualization, economic analysis, and manuscript writing. All authors contributed to the critical revision and approved the final version of the manuscript.

Funding

This study was funded by the authors, with no external funding sources.

Use of artificial intelligence (AI)

No AI technologies or AI-assisted technologies were used during the preparation of this work.

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