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Daucus carota L. as a source of natural pigment and its effect on zootechnical parameters in Cobb 500 broiler chickens

Daucus carota L. como fuente de pigmento natural y su efecto sobre los parámetros zootécnicos en pollos de engorde Cobb 500

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Abstract

This study evaluated the effect of carrot flour (CF; *Daucus carota* L.) as a partial substitute for the basal diet of Cobb 500 broiler chicken on skin pigmentation, production parameters and profitability. A total of 64 chickens were separated according to sex and assigned to four diets, with four replicates of two birds each. The control groups were fed a standard diet, and the experimental groups were fed the same conventional diet with replacement levels of 10, 15, and 20% CF. No significant differences were observed in feed consumption, weight gain or feed conversion ratio. However, diets with carrot flour improved feed intake, promoted weight gain and optimized feed efficiency with 10% in males and 15% in females. No mortality was recorded in the experimental groups. The intensity of pigmentation in the chickens' skin increased as the level of substitution increased, while sex influenced color expression. Diets with CF improved profitability especially in males. In conclusion, the replacement of the basal diet with CF in the diet of Cobb 500 broilers had positive effects on the evaluated parameters, therefore, it can be used as an alternative source of natural pigment in the production of yellow-skinned broilers.

Keywords: pigmentation; carotenoids; poultry production; *Daucus carota*; carrot flour.

Resumen

Este estudio evaluó el efecto de la harina de zanahoria (HZ; *Daucus carota* L.) como sustituto parcial de la dieta basal de pollos de engorde Cobb 500 sobre la pigmentación de la piel, parámetros productivos y rentabilidad. Un total de 64 pollos fueron separados según el sexo y se asignaron a cuatro dietas, con cuatro réplicas de dos aves cada una. Los grupos testigos fueron alimentados con una dieta estándar y los grupos experimentales recibieron la misma dieta convencional con niveles de reemplazo del 10, 15 y 20% de HZ. No se observaron diferencias significativas en el consumo de alimento, ganancia de peso o índice de conversión alimenticia. Sin embargo, las dietas con harina de zanahoria mejoraron el consumo de alimento, promovieron el aumento de peso y optimizaron la eficiencia alimenticia con un 10% en machos y un 15% en hembras. No se registró mortalidad en los grupos experimentales. La intensidad de la pigmentación en la piel de los pollos aumentó a medida que se incrementó el nivel de sustitución, mientras que el sexo influyó en la expresión del color. Las dietas con HZ mejoraron la rentabilidad especialmente en los machos. En conclusión, la sustitución de la dieta basal con HZ en la dieta de los pollos de engorde Cobb 500, tuvo efectos positivos en los parámetros evaluados; por tanto, puede usarse como fuente alternativa de pigmento natural en la producción de pollos de engorde de piel amarilla.

Palabras clave: pigmentación; carotenoides; producción avícola; *Daucus carota*; harina de zanahoria.

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Introduction

The poultry industry has made grand-scale production possible thanks to advancements in genetics, reproduction, health and nutrition, allowing for greater growth rates and optimized egg production. (Kleyn y Ciacciariello, 2021; Martínez et al., 2021). These advancements have help to meet the high demand for poultry products, such as meat and eggs, which are crucial sources of animal protein (Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), 2023).

Nowadays, one of the key aspects of poultry production is improving the quality of the meat through nutritional strategies, designed to modify the properties that influence the general acceptability of the product. Among these properties, meat and skin is the most important attribute, because it is the first feature to be perceived by the senses, and the one consumers associate with both quality and healthiness (Ortiz et al., 2022; Pandiselvam et al., 2023). Although pigmentation, in practical terms, is not a reliable sign of quality and safety, it does influence the consumer's perception of the product and their inclination to buy it; therefore, pigmentation becomes economically important as well (de Araújo et al., 2022).

In Ecuador, studies have shown preference for yellow skin as an indicator of fresh safe and nutritious food (Vargas, 2015; Toalombo et al., 2019). Nonetheless, the broiler chicken lines have not managed to obtain the adequate color intensity naturally, because they cannot synthesize carotenoids in vivo. Thus, these pigments have to be supplemented through diet (Wu et al., 2021).

As a result, the balanced feed industry adds pigments, natural or synthetic, to the diet for yellow-skin chicken production (Marounek y Pebriansyah, 2018). Although the synthetic pigments are subjected to safety tests and strict regulations, there is growing concern in consumers about health, both their own and the chicken's, and demand for natural pigment also grows (Rana et al., 2021).

In this context, the most important source of carotenoids is yellow maize, but it does not contribute enough to pigmentation to meet the demands of the consumer (Moreno et al., 2020). Consequently, food pigments are used, such as: saffron (*Crocus sativus*), calendula flower (*Calendula officinalis*), paprika (*Capsicum annunm*), alfalfa (*Medicago sativa*) and annatto (*Bixa orellana*) to improve the color of the skin, meat and egg yolk. Nonetheless, the commercial viability of these feeding programs is limited by the high cost of diets that include these pigments (Farkas et al., 2020; Surai y Kochish, 2020; Martínez Cámara et al., 2021).

With this challenge, Ürüşan et al. (2018), Khan (2019), Ng'Ambi et al. (2019), Widya et al. (2019) y Dabai et al. (2021), have documented the potential for broiler chicken feeding of carrot-derived products , like leave and seed extract, juice, the fleshy part of the napiform root (root pulp), and the scraps. These studies revealed significant improvements on skin pigmentation, digestion, body-weight gain, feed convertion rate, and poultry immune response. Nonetheless, scientific evidence for the use of carrots in Cobb 500 chicken broiler feeding, and reports of its profitability are non-existant. Therefore, the objective of the research was to evaluate the effects of carrot flour (*Daucus carota* L.), as a partial substitute for the basal diet of Cobb 500 broiler chicken, on pigmentation, production indicators and profitability.

Materials and methods

Location

The experiment took place at the Rio Suma Experimental Farm, located on the premises of the Faculty of Agricultural Engineering, Universidad Laica Eloy Alfaro de Manabí, El Carmen campus, province of Manabí, Ecuador, with geographical coordinates -0.262655 S and -79 .427579 E, and a humid tropical climate. This area is located at an altitude of 263 meters above sea level, with an average temperature of 24 °C, an annual precipitation of 2,806 mm, a relative humidity of 86%, a solar exposure of 1,026 light hours per year and an annual evaporation of 1,064 mm. (National Institute of Meteorology and Hydrology (INAMHI), 2019).

Experimental design

A completely randomized experimental design (DCA) was applied with a factorial arrangement A (sex) x B (carrot flour levels) with four repetitions, each consisting of two birds. The treatments consisted of a control diet and three experimental diets in which the conventional food was replaced by carrot flour in proportions of 10, 15 and 20%, as detailed in table 1.

Table 1. Experimental groups.

Factor A	Factor B			
	Control (b1)	10% HZ (b2)	15% HZ (b3)	20% HZ (b4)
Female (a1)	a1+b1	a1+b2	a1+b3	a1+b4
	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Male (a2)	a2+b1	a2+b2	a2+b3	a2+b4
	Treatment 5	Treatment 6	Treatment 7	Treatment 8

Nota: HZ: carrot flour.

Experiment management

A total of 64 5-day-old chicks were used, with an initial average weight of 45 g, who were housed in a rearing circle in a shed for 14 days. After 15 days, they were separated by sex, and then randomly distributed in experimental units. In the first three weeks, all birds received an standard diet following the nutritional requirements for each stage. From then to the final stage, on week 5, they were given fattening feed with the carrot flour included.

The carrot flour came from a food processing company (no branding). afterwards, in order to determine the nutritional composition, a sample was sent to a local laboratory for bromatologic analysis, while the nutritional values for the balanced feed used in the formulation of the diet were obtained from the table of food composition (table 2).

Table 2. Nutritional composition of the diets.

Variable	Balanced feed	Carrot flour
(%) Humidity	13	9.10
(%) Protein	18	8.62
(%) Ether ext.	5	1.32
(%) Ash	7	5.73
(%) Fiber	4	7.54

Evaluation method

During the experiment, the birds were weighed weekly, while the food intake was measured daily (given feed/ rejected feed). The following variables were established when the experimentation stage ended:

Daily average intake ($g \cdot bird^{-1}$): This value was obtained by dividing the sum of the food consumption records by the number of birds.

Average weight gain ($g \cdot bird^{-1}$): This variable was calculated by adding the differences between the final weight and the initial weight of each bird, and then dividing by the total number of birds in the treatment.

Food conversion index: To obtain the value of this variable, the total amount of food consumed was divided by the total amount of weight gain experienced.

Mortality (%): It was obtained by dividing the total number of chickens that died during the observation period by the initial number of chickens with which treatment began, and then multiplying the result by 100.

Pigmentation: The evaluation of skin pigmentation of chickens was carried out using the Rocher scale. This procedure involved measuring and recording the intensity of pigmentation in the skin of each chicken individually, at the time of slaughter. Each chicken was assigned a numerical value based on the intensity of its skin pigmentation. Subsequently, the average of the recorded values was calculated.

Profitability: It was calculated through the benefit/cost formula, considering only the feeding costs and the income derived from the sale of chickens based on their weight. A value greater than 1 indicated that the project was profitable (Rebollar et al., 2020).

Data Analysis

It was calculated through the benefit/cost formula, considering only the feeding costs and the income derived from the sale of chickens based on their weight. A value greater than 1 indicated that the project was profitable (Rebollar et al., 2020).

Results and discussion

The results of the analysis of variance presented in table 3 indicated that the different levels of carrot flour used as a partial substitute for the basal diet of broiler chickens did not have a significant impact on any of the parameters evaluated ($P>0.05$). This finding was similar to that reported by Khan (2019), who replaced a proportion of corn with carrot pulp meal in the diet of Hubbard chickens and found no significant differences in feed intake, body weight and conversion rate.

Feed intake

Even though no significant statistical differences were found, the data in Table 3 showed that males consumed more food than females in all treatments. This trend coincided with what was reported by Jácome-Gómez et al. (2023) in relation to the greater feed intake by male chickens of the Cobb 500 line compared to females. Furthermore, it was observed that feed consumption increased as the percentages of carrot flour in the diet increased, which agreed with what was described by Noviadi and Maradon (2021) and confirmed the influence of HZ on the eating behavior of the animals. chickens, noted by Ng'Ambi et al. (2019).

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It is possible that the chickens' response in this parameter was related to the lower protein content in the carrot flour portion, which led to an increase in feed intake to balance the protein level required to maintain growth. as mentioned by Jabbar et al. (2021).

Weight gain

Regarding weight gain, it was observed that males gained greater weight compared to females, regardless of the quantity of carrot flour. This was in line with the general trend that the sex of chickens plays a crucial role in productivity, with a faster growth rate and greater weight gain in males than in females, regardless of other factors such as diet. or breeding systems (Benyi et al., 2015; Cygan-Szczegielniak et al., 2019).

On the other hand, among the treatments, the highest weight gain was found in the group of males with 20% HZ (2,809 g), while in the group of females the highest weight gain was recorded in the birds with 15% substitution (2,649.63 g). It is relevant to note that, although these values were slightly lower than the reference standards, the control groups obtained lower values, which suggests that carrot flour improved the weight of the chickens. The amount of fiber present in carrot flour could have partially explained these results, since it is a component that helps regulate the digestion of birds and contributes to the use of nutrients, as noted by Widya et al. (2019).

Food conversion

Regarding feed conversion, the results indicated that, in general, males had greater efficiency compared to females. This variability could be related to the physiological differences between males and females in terms of metabolism, nutritional requirements, and hormonal interactions that influence how chickens use and digest nutrients (Cui et al., 2021).

Taking into account that feed conversion is the indicator that reflects the amount of feed necessary to produce a unit of body weight, and generally, a lower value indicates greater efficiency in the production process (Prakash et al., 2020), the results showed that, for females, replacing the basal diet with 15% carrot flour was beneficial, while for males, 10% carrot flour was more efficient compared to the control groups. These improvements in feeding efficiency could be related to the presence of carotenoids, precursors of vitamin A, in carrot flour. According to Khan et al. (2023) these compounds, at optimal concentrations, had positive effects on nutrient digestibility and feed conversion rate.

Table 3. Statistical comparison of zootechnical parameters.

Treatment	Sex	HZ (%)	Feed intake (g)	Weight gain (g)	Food conversion
1	Female	Control	3,713.63 ^{b}	2,366.00 ^{a}	1.57 ^{a}
2	Female	10	4,126.88 ^{ab}	2,384.63 ^{a}	1.73 ^{a}
3	Female	15	4,145.75 ^{ab}	2,649.63 ^{a}	1.56 ^{a}
4	Female	20	4,225.63 ^{ab}	2,352.88 ^{a}	1.80 ^{a}
5	Male	Control	3,988.32 ^{ab}	2,543.38 ^{a}	1.57 ^{a}
6	Male	10	4,230.19 ^{ab}	2,725.63 ^{a}	1.55 ^{a}
7	Male	15	4,501.07 ^{a}	2,758.50 ^{a}	1.63 ^{a}
8	Male	20	4,475.07 ^{a}	2,809.00 ^{a}	1.59 ^{a}

Note: medians with the same letters are not significant (P>0.05).

Mortality

The results of table 4 revealed that mortality in all experimental groups was 0%, while in the control groups for both sexes they presented a mortality rate of 12.50%, which indicated that the inclusion of carrot flour in chicken diets, in the percentages evaluated, had a positive impact on the survival of the birds. This result was in line with what was pointed out by Silondae et al. (2023) who highlighted the use of carrots as a source of essential antioxidants to improve the health of chickens, and consequently reduce the percentage of losses due to death.

Table 4. Mortality of chicken broiler.

Treatment	Sex	HZ (%)	Mortality
1	Female	Control	12.50
2	Female	10	0.00
3	Female	15	0.00
4	Female	20	0.00
5	Male	Cintrol	12.50
6	Male	10	0.00
7	Male	15	0.00
8	Male	20	0.00

Note: HZ: Carrot flour.

Pigmentation

Carrot flour as a partial substitute for the basal diet of broilers had a positive effect on skin pigmentation. Furthermore, an increase in color intensity was observed as the percentage of substitution increased, in both females and males. However, it is important to note that males exhibited higher pigmentation compared to females, which could be related to the amount of food consumed. In the case of males, having ingested greater amounts of food, also incorporating a greater amount of carotenoids (table 5).

In general, the results indicated that carrot flour improved the skin pigmentation of the chickens, contrary to what was stated by Azizah et al. (2017) in which no change was observed in the skin color of Lohmann broilers when they included carrot waste meal in the feed. One reason for these differences could be the decrease in the concentration of carotenoids in the waste due to the extraction process (Otálora-Orrego y Martin, 2021).

Table 5. Effect of carrot flour on skin pigmentation according to sex.

Treatments	Sex	HZ (%)	Pigmentation
1	Female	Control	0.25
2	Female	10	2.25
3	Female	15	3.25
4	Female	20	5.50
5	Male	Control	0.50
6	Male	10	2.75
7	Male	15	4.75
8	Male	20	6.00

Nota: HZ: carrot flour.

Profitability

The results of the economic analysis, presented in Table 6, showed that the partial substitution of carrot flour in the diet of broiler chickens had a positive effect on profitability. In particular, in the female group, the 15% HZ treatment showed the highest income and a more favorable B/C ratio, while, in the male group, the 20% HZ treatment generated the highest income. However, treating males with 10% carrot flour reported the lowest cost and the best B/C ratio. Because studies on the pigmentation characteristics of various carotenoid sources often place less emphasis on cost-effectiveness, it was difficult to compare the findings of this study with previous research, especially in the case of carrot flour which has been less explored.

In summary, this study provided preliminary evidence of the possible benefits of using carrot flour in the production of broiler chickens of the Cobb 500 line. These benefits were reflected in both productive performance and economic profitability, presenting an excellent opportunity to eliminate or reduce the use of artificial pigments in poultry production. These findings may be valuable to the poultry industry and decision making in diet formulation. Likewise, the results are of particular importance for small poultry producers in the municipality of El Carmen, Manabí, since it provides them with an alternative to adapt their production strategies so that they satisfy the preferences of local consumers.

Table 6. Economic analysis of the effect of carrot flour on the pigmentation of broiler chickens according to sex.

Treatment	Sex	HZ (%)	Income	Cost	B/C
1	Female	Witness	40.08	29.95	1.34
2	Female	10	54.56	35.60	1.53
3	Female	15	60.62	35.72	1.70
4	Female	20	53.83	36.25	1.49
5	Male	Witness	43.08	31.55	1.37
6	Male	10	62.36	36.28	1.72
7	Male	15	63.11	38.08	1.66
8	Male	20	64.27	37.90	1.70

Nota: HZ: carrot flour.

This study has limitations. First, the lack of analysis of the carotenoid contents in carrot flour made the result interpretation harder.It is recommended to carry out this analysis in further research. Second, the purchase of carrot flour influenced the feeding costs. For further research it is recommended to assess the viability of local carrot flour production.Lastly, the main limitation of the study ewas the color measurement, because using the YolkFan DSM may lead to inacurrate measurements caused by subjectivity, human fatigue and light variations. Further studies may overcome this limitiation by using reflectance photometry.

Conclusion

Carrot flour, as substitute in basal diets, had positive effects in the skin pigmentation of chickens, regardless of sex. With 10%, a mild degree of pigmentation with a subtle yellow hue was achieved; with 15%, a pale yellow color; and with 20%, a more intense and defined yellow. Likewise, carrot flour improves weight gain and the food efficiency index, particularly in males, when a 15% carrot flour is added to the feed. Additionally, it has proved to be profitable, especially with males. These

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findings can be very relevant in the decision-making poultry and cattle production.

Conflict of interests

The authors declare that they have no conflicts of interest in this publication in any of its phases.

Bibliographic references

Azizah, N. A., Mahfudz, L. D. and Sunarti, D. (2017). Kadar lemak dan protein karkas ayam broiler akibat penggunaan tepung limbah wortel (*Daucus carota* L.) dalam *Ransum. Journal Sain Peternakan Indonesia*, *12*(4), 389-396. https://doi.org/10.31186/jspi.id.12.4.389-396

Benyi, K., Tshilate, T. S., Netshipale, A. J. and Mahlako, K. T. (2015). Effects of genotype and sex on the growth performance and carcass characteristics of broiler chickens. *Tropical Animal Health and Production*, *47*, 1225-1231. DOI: 10.1007/s11250-015-0850-3

Cui, L., Zhang, X., Cheng, R., Ansari, A. R., Elokil, A. A., Hu, Y., Chen, Y., Nadafy, A. A.and Liu, H. (2021). Sex differences in growth performance are related to cecal microbiota in chicken. *Microbial Pathogenesis*, *150*, 104710. https://doi.org/10.1016/j.micpath.2020. 104710

Cygan-Szczegielniak, D., Maiorano, G., Janicki, B., Buzała, M., Stasiak, K., Stanek, M., Roślewska, A., Elminowska-Wenda, G., Bogucka, J., and Tavaniello, S. (2019). Influence of rearing system and sex on carcass traits and meat quality of broiler chickens. *Journal of Applied Animal Research*, *47*(1), 333-338. https://doi.org/10.1080/09712119.2019. 1634076

Dabai, S. A., Bello, S. and Dabai, J. S. (2021). Growth performance and carcass characteristics of finisher broiler chickens served carrot leaf extract as a supplementary source of vitamins and minerals. *Nigerian Journal of Animal Science*, *23*(1), 144-149. https://www.ajol.info/index.php/tjas/article/view/212020

de Araújo, P. D., Araújo, W. M. C., Patarata, L. and Fraqueza, M. J. (2022). Understanding the main factors that influence consumer quality perception and attitude towards meat and processed meat products. *Meat Science*, *193*, 108952. https://doi.org/10.1016/j.meatsci. 2022.108952

Farkas, Á., Bencsik, T. and Deli, J. (2020). Carotenoids as food additives. P. 421-447. *In:* Jacob-Lopes, E., Queiroz, M. I., and Queiroz Zepka, L. (Eds.). *Pigments from Microalgae Handbook*. First edition. Suiza: Springer.

Instituto Nacional de Meteorología e Hidrología. (2019). *INAMHI-Precipitación-2019Diciembre.csv*.https://www.datosabiertos.gob.ec/dataset/precipitacion-total-mensual/ resource/98c77d18-e863-4e00-8a22-eb47f2981d9c

Jabbar, A., Tahir, M., Khan, R. U. and Ahmad, N. (2021). Interactive effect of exogenous protease enzyme and dietary crude protein levels on growth and digestibility indices in broiler chickens during the starter phase. *Tropical Animal Health and Production*, *53*, 1-5. https://doi.org/10.1007/s11250-020-02466-5

Jácome-Gómez, J. R., Sánchez, E. J. S., Mendoza, M. E. Z., De la Cruz Chicaiza, M. V. y Anchundia, M. Á. M. (2022). Efecto de diferentes materiales de cama sobre el comportamiento productivo de pollos de engorde Cobb 500. *Ciencia Latina Revista Científica Multidisciplinar*, *6*(5), 3868-3881. https://doi.org/10.37811/cl_rcm.v6i5.3362

Khan, R. U., Khan, A., Naz, S., Ullah, Q., Puvača, N., Laudadio, V., Mazzei, D., Seidavi, A., Ayasan, T., and Tufarelli, V. (2023). Pros and cons of dietary vitamin A and its precursors in poultry health and production: A comprehensive review. *Antioxidants*, *12*(5), 1131. https://doi.org/10.3390/antiox12051131

Khan, S. (2019). Utilization carrot pulp as corn replacement in the broiler diet. *IOSR-JAVS*, *12*, 72-4. DOI: 10.9790/2380-1202027274

Kleyn, F. J. and Ciacciariello, M. (2021). Future demands of the poultry industry: will we meet our commitments sustainably in developed and developing economies?. *World's Poultry Science Journal*, *77*(2), 267-278. https://doi.org/10.1080/00439339.2021.1904314

Marounek, M., and Pebriansyah, A. (2018). Use of carotenoids in feed mixtures for poultry: a review. *Agricultura Tropica et Subtropica*, *51*(3), 107-111. https://doi.org/10.2478/ats-2018-0011

Martínez, Y., Orozco, C. E., Montellano, R. M., Valdivié, M. and Parrado, C. A. (2021). Use of achiote (*Bixa orellana* L.) seed powder as pigment of the egg yolk of laying hens. *Journal of Applied Poultry Research*, *30*(2), 100154. https://doi.org/10.1016/j.japr.2021.100154

Martínez-Cámara, S., Ibañez, A., Rubio, S., Barreiro, C. and Barredo, J. L. (2021). Main carotenoids produced by microorganisms. *Encyclopedia*, *1*(4), 1223-1245. https://doi.org/10.3390/encyclopedia1040093

Mir, N. A., Rafiq, A., Kumar, F., Singh, V. and Shukla, V. (2017). Determinants of broiler chicken meat quality and factors affecting them: a review. *Journal of food science and technology*, *54*, 2997-3009. DOI: 10.1007/s13197-017-2789-z

Moreno, J. A., Díaz-Gómez, J., Fuentes-Font, L., Angulo, E., Gosálvez, L. F., Sandmann, G., Portero-Otin, M., Capell, T., Zhu, C., Christou, P. and Nogareda, C. (2020). Poultry diets containing (keto) carotenoid-enriched maize improve egg yolk color and maintain quality. *Animal Feed Science and Technology*, *260*, 114334. https://doi.org/10.1016/j.anifeedsci.2019.114334

Ng'Ambi, J. W., Mokgope, P. K., Brown, D. and Manyelo, T. G. (2019). Effect of dietary carrot meal supplementation on productivity and carcass characteristics of Arbor acre broiler chickens aged 22 to 42 days. *Applied Ecology & Environmental Research*, *17*(5), 12337-12346. https://lc.cx/gXkiyh

Noviadi, R. and Maradon, G. G. (2021). Broiler performance given carrot waste juice meal as a feed supplement. *International Conference on Agriculture and Applied Science*. 146-150. https://doi.org/10.25181/icoaas.v1i1.2068

Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). (2023). *Producción avícola*. https://www.fao.org/poultry-production-products/production/es/

Ortiz, D., Lawson, T., Jarrett, R., Ring, A., Scoles, K. L., Hoverman, L., Rocheford, E., Karcher, D.M. and Rocheford, T. (2022). Applied Research Note: The impact of orange corn in laying hen diets on yolk pigmentation and xanthophyll carotenoid concentrations on a percent inclusion rate basis. *Journal of Applied Poultry Research*, *31*(1), 100218. https://doi.org/10.1016/j.japr.2021.100218

Otálora-Orrego, D. y Martin, D. A. (2021). Técnicas emergentes de extracción de β-caroteno para la valorización de subproductos agroindustriales de la zanahoria (*Daucus carota* L.): una revisión. *Informador Técnico*, *85*(1), 83-106. https://doi.org/10.23850/22565035.2857

Pandiselvam, R., Mitharwal, S., Rani, P., Shanker, M. A., Kumar, A., Aslam, R., Tekgül Barut, Y., Kathakota, A., Rustagi, S., Bhati, D., Anusha Siddiqui, S., Wasin Siddiqui, M., Ramniwas, S., Aliyeva, A. and Khaneghah, A. M. (2023). The influence of non-thermal technologies on color pigments of food materials: An updatedreview. *Current Research in Food Science*, 100529. https://doi.org/10.1016/j.crfs.2023.100529

Prakash, A., Saxena, V. K. and Singh, M. K. (2020). Genetic analysis of residual feed intake, feed conversion ratio and related growth parameters in broiler chicken: A review. *World's Poultry Science Journal*, *76*(2), 304-317. https://doi.org/10.1080/00439339.2020.1735978

Rana, B., Bhattacharyya, M., Patni, B., Arya, M. and Joshi, G. K. (2021). The realm of microbial pigments in the food color market. *Frontiers in Sustainable Food Systems*, *5*, 603892. https://doi.org/10.3389/fsufs.2021.603892

Rebollar, S., Posadas, R. R., Rebollar, E., Hernández, J. and González, F. D. J. (2020). Aportes a indicadores de evaluación privada de proyectos de inversión. *Revista Mexicana de Agronegocios*, *46*(444-461). http://dx.doi.org/10.22004/ag.econ.303885

Silondae, H., Polakitan, D., Paat, P. C., Kairupan, A. N., Layuk, P., Lintang, M., Joseph, G. H., Polakitan, A., Tandi, O. G., Markus Rawung, J. B., Rembang, J. H. W., Salamba, H. N., Malia. I. E., Sondakh, J. O. M., Hutapea, R. T. P., Kindangen, J. G. and Elizabeth, R. (2023). The effects of carrot (*Daucus carota* L.) waste juice on the performances of native chicken in North Sulawesi, Indonesia. *Open Agriculture*, *8*(1), 20220173. https://doi.org/10.1515/opag-2022-0173

Surai, P. F., and Kochish, I. I. (2020). Carotenoids in Aviculture. p. 515-540. In: Jacob-Lopes, E., Queiroz, M. I., and Queiroz Zepka, L. (Eds.). *Pigments from Microalgae Handbook*. First edition. Suiza. Springer.

Toalombo, P. A., Camacho, C. A., Buenaño, R., Jiménez, S., Navas-González, F. J., Landi, V. y Delgado, J. V. (2019). Efecto socioeconómico sobre las características fanerópticas de gallinas autóctonas de Ecuador. *Archivos de Zootecnia*, *68*(263), 416-

LA TÉCNICA
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421. https://doi.org/10.21071/az.v68i263.4202

Ürüşan, H., Erhan, M. K. and Bölükbaşı, S. C. (2018). Effect of cold-press carrot seed oil on the performance, carcass characteristics, and shelf life of broiler chickens. *JAPS: Journal of Animal & Plant Sciences*, *28*(6), 1662-1668. https://www.cabdirect.org/cabdirect/ abstract/20193004826

Vargas González, O. N. (2015). *Avicultura*. Machala, Ecuador: Ediciones UTMACH. 134 p.

Widya Paramita, L., Novryantoro, V., Wibowo, M. L. and Ananda, A. T. (2019). An utilization of carrot tuber juice (*Daucus carota* L.) to increase average daily gain in broiler chickens: Reinventing food security through chicken livestock. 223 *Proceeding Book 7th Asian Academic Society International Conference 2019.* https://core.ac.uk/download/pdf/ 288223943.pdf

Wu, J., Lin, Z., Chen, G., Luo, Q., Nie, Q., Zhang, X. and Luo, W. (2021). Characterization of chicken skin yellowness and exploration of genes involved in skin yellowness deposition in chicken. *Frontiers in Physiology*, *12*, 585089. https://doi.org/10.3389/fphys.2021. 585089

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María Cristina Martínez-Sotelo	Research design and writing the manuscript.
Diana Leticia de La Cruz Chicaiza	Economical analysis and writing the manuscript.