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Nutritional assessment of rabbit manure as feed supplement for Ross AP broilers

Valoración nutricional de las heces de conejo como suplemento alimenticio en pollos Ross AP

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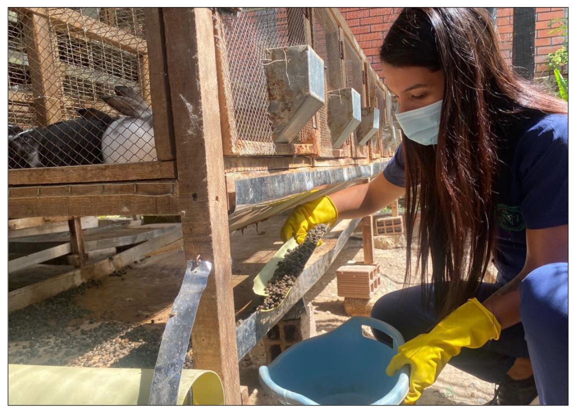

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ABSTRACT

Advances in genetics, nutrition, housing, and management practices have substantially benefited the poultry industry. In Colombia, poultry farming faces numerous challenges related to health and feed, the latter being a limiting problem due to its high cost. In this context, low-cost feeds are presented as an alternative to improve profitability. It is advantageous, therefore, to explore new options for broiler rearing. As part of this search, the use of rabbit manure as a low-cost feed supplement was proposed. With this objective, the impact of rabbit manure on the weight gain and growth of Ross AP line chickens during the initiation, growth, and fattening stages was evaluated by calculating the levels of protein (Pb), fiber (Fb), moisture (H), fat (Gr) and ash (Cen) in the manure, previously subjected to dehydration and milling. This research was conducted in the Sartenejal village, located south of the municipality of Guadalupe, Huila.

For the study, 44 specimens were randomly divided into 4 groups of 11 chickens each, which received a specific percentage of rabbit manure in their diet: T1 (10%), T2 (30%), T3 (50%), and a control group (0%) relative to the total feed mixture. This trial lasted 45 days. The results showed that a mixture of 10% rabbit manure and 90% poultry feed produced a significant weight gain of 2471.18 grams. However, a diet high in fiber and protein, such as the 30% and 50% rabbit manure mixes, is not recommended nor satisfactory for broiler breeding, as it does not significantly promote weight gain.

Keywords: control; diet; fiber; feces; protein; rations; supplement.

RESUMEN

Los avances en genética, nutrición, alojamiento y prácticas de manejo han beneficiado sustancialmente a la industria avícola. En Colombia, la avicultura enfrenta numerosos retos relacionados con la sanidad y la alimentación, siendo esta última un problema limitante debido a su alto costo. En este contexto, los piensos de bajo coste se presentan como una alternativa para mejorar la rentabilidad. Por lo tanto, resulta ventajoso explorar nuevas opciones para la cría de pollos de engorde. Como parte de esta búsqueda, se propuso el uso de estiércol de conejo como suplemento alimenticio de bajo coste. Con este objetivo se evaluó el impacto de la conejaza sobre la ganancia de peso y el crecimiento de pollos de la línea Ross AP durante las etapas de iniciación, crecimiento y engorde, mediante el cálculo de los niveles de proteína (Pb), fibra (Fb), humedad (H), grasa (Gr) y cenizas (Cen) en el estiércol, previamente sometido a deshidratación y molienda. Esta investigación se realizó en la vereda Sartenejal, ubicada al sur del municipio de Guadalupe, Huila. Para el estudio se dividieron aleatoriamente 44 ejemplares en 4 grupos de 11 pollos cada uno, los cuales recibieron un porcentaje específico de estiércol de conejo en su dieta: T1 (10%), T2 (30%), T3 (50%) y un grupo testigo (0%), respecto a la mezcla total con el concentrado. El estudio tuvo una duración de 45 días. Los resultados mostraron que una mezcla de 10% de conejaza con 90% de concentrado produjo una ganancia de peso significativa de 2471,18 gr. Sin embargo, se concluyó que una dieta rica en fibra y proteína como la mezcla de conejaza en porcentajes de 30% y 50% no es recomendable ni satisfactoria para la cría de pollos de engorde, puesto que no favoreces ignificativamente el aumento de peso.

Palabras clave: dieta; fibra; heces; proteina; raciones; suplemento; testigo.

INTRODUCTION

Colombia, a country with fluctuating domestic meat production, has substantially increased supplement costs for broilers and laying hens. This increase, ranging from 60% to 70%, significantly impacts poultry farming (Asmar, 2021).

Concentrates are indispensable for poultry feed, given the strategic importance of the poultry sector. To enhance production efficiency and competitiveness, the industry aims to offer high-quality products through fiber-rich diets. These diets facilitate the absorption of easily digestible nutrients, promoting weight gain and improving poultry flavor (Dorado et al., 2024). The poultry sector can reduce economic dependence on imported feed ingredients by utilizing local resources such as fruits, tubers, grains, and palatable leaves. This approach can decrease feeding costs while providing essential nutrients like healthy acids, carotenoids, fiber, and trace elements (Saeed et al., 2024).

Consequently, this strategy lessens the reliance on countries like the United States, China, Brazil, France, Germany, Spain, India, Argentina, Thailand, Russia, and Canada, which supply a variety of feed components including corn, soybeans, wheat, barley, sorghum, and vitamin-mineral supplements (Cascavita & Colorado, 2023).

There is a need to source supplies from other regions given the substantial demand for poultry feed in Colombia. Companies like Italcol in Tolima and Valle del Cauca offer a variety of broiler chicken lines, including traditional breeds, farm-raised, and high-tech production systems. In some regions, these lines may also produce yellow-fleshed birds, known as the ‘golden line’.

Italcol brand offers starter feeds for broiler chickens, designed for the initial growth phase. These feeds are characterized by a high protein content (21%), moderate fat (2%), and adequate levels of moisture (13%), fiber (5%), and ash (8%). As chickens transition to the grower phase, the protein content in Italcol’s broiler feed decreases slightly to 19%, while other nutrients remain relatively consistent. In a 2017 study, Italcol’s feed was compared with commercial brands Contegral and Solla, as well as a corn and leucaena-based diet. The findings revealed that Italcol’s feed performed worse than the commercial brands over the 42-day trial period (Mindiola et al., 2017).

Querying for alternative feed sources for broiler chickens is essential, given the dominance of Italcol and Contegral in the Colombian market. Researchers have investigated the inclusion of plantain meal in broiler diets at various concentrations, including 100%, 75%, and 50% (Delgado et al., 2013). Additionally, studies have examined the use of wheat bran as a fiber source in broiler diets, particularly for the Cobb 500 genetic line (Lin et al., 2023).

Finely ground fiber supplements have been explored to optimize the impact of fiber on the intestinal tract. A study with Ross 308 genetics incorporated soluble wheat into the diet to replace corn starch, leading to improved microbial fermentation and digestion (Dorado et al., 2024).

The inclusion of excessive insoluble fiber in poultry feed can lead to several alterations in the digestive tract. Due to its resistance to digestion, insoluble fiber can hinder the absorption of fatty acids in the intestinal epithelium (Lannuzel et al., 2022). Moreover, the presence of excessive fiber can result in the retention of solutes, thereby impairing nutrient absorption. This can affect various segments of the gastrointestinal tract, including the crop, gizzard, small intestine, and cecum (Garçon et al., 2023; Bortoluzzi et al., 2023).

Several investigations explore the use of fiber from various sources in animal and poultry feeding, rabbits, for example, exhibit cecotrophy, a behavior where they consume their own soft, dark feces, which are rich in vitamin B12 (Romero, 2008; Melo et al., 2022; García-Sánchez et al., 2023; Jalabe-Lagos & Meneses-Prado, 2021). Rabbits practice cecotrophy to supplement their diet with essential nutrients, especially when vitamin B12 is deficient (Aquarium, 2021). This behavior is particularly important during the breeding stage when young rabbits consume their mother's cecotrophs, establishing a lifelong habit.

The cecum, a pouch-like structure at the junction of the small and large intestines, is a highly microbial-dense environment (García-Vázquez et al., 2021). This microbial community plays a critical role in various physiological processes, including digestion, nutrient absorption, and potentially, immune modulation.

Herbivorous, such as rabbits and rodents, exhibit a unique behavior known as cecotrophy, whereby they consume their own feces. This practice allows for the recycling of nutrients and the transfer of beneficial microbes to the foregut. Recent studies have suggested that cecotrophy may also contribute to immune function by influencing the composition and activity of the intestinal microbiota (Santos-Ricalde et al., 2023; Usakura, 2022).

Rabbit feces are a valuable source of nutrients, containing approximately 60% protein and 30% water. The amino acid profile of rabbit feces can vary depending on the rabbit's diet and the specific microbial communities present in the gastrointestinal tract (Brenes-Payá et al., 1978).

Rabbit feces are rich in nitrogen, phosphorus, potassium, and a variety of minerals and trace elements, including calcium, magnesium, boron, zinc, manganese, sulfur, copper, cobalt, and others (Rubio et al., 2023). Notably, the nitrogen content in rabbit feces can be as high as 1.94% (Sarzosa et al., 2022).

Given the historical use of rabbit feces as a feed ingredient for sheep (Reyes-Rodríguez & Castillo-Ortiz, 1994), it is plausible that rabbit feces could be used as a supplement for poultry, potentially reducing feed costs compared to commercial products exclusively."

A diet incorporating rabbit feces can potentially lead to a reduction in fatty tissues due to its high fiber content. This reduction can affect organs such as the heart, liver, gizzard, and abdominal wall, potentially resulting in morphological changes (Londok & Rompis, 2021; Saragih et al., 2023).

Reducing the fat content in poultry meat results in a higher-quality product that appeals to consumers who seek healthy, low-fat options (Sevim et al., 2021; Gou et al., 2021; Godoy et al., 2024). Reduced fat content in poultry meat can contribute to improved heart health and overall well-being.

Since there is limited scientific literature on the use of rabbit feces as a dietary supplement for poultry, this research aimed to explore its potential benefits. Specifically, the study sought to determine if the inclusion of rabbit feces into poultry feed could contribute to the production of poultry with lower fat content and enhanced visual appeal.

A previous research conducted in Mexico has explored the potential of using animal feces as a feed ingredient. In 1994 a study at the University of Guadalajara investigated the inclusion of rabbit, pig, bovine, and chicken feces in sheep diets. The results suggested that these sources could be valuable feedstuff, providing essential nutrients such as nitrogenous compounds, which could also be beneficial for poultry feed (Reyes-Rodríguez & Castillo-Ortiz, 1994).

In a subsequent study published in 2007, the same authors investigated the nutritional value of diets based on animal feces. They found that chicken manure, in particular, is a rich source of nutrients, containing 22.3% crude protein, 2.9% ether extracts, 39.5% crude fiber, 28% nitrogen-free extracts, 14% ash, and 4.9% moisture. Based on these results, it was concluded that chicken manure could be a cost-effective feed ingredient for ruminants, particularly at a concentration of 35%.

MATERIAL AND METHODS

Location. The study was conducted at the El Ruiseñor productive unit, located in the Sartenejal trail within the municipality of Guadalupe, Huila. The farm is located at 1.996576, -75.742971, with an altitude of 970 meters above sea level. The region has a tropical climate with temperatures of 30°C in summer and 22°C in winter (Cenicafe, 2024).

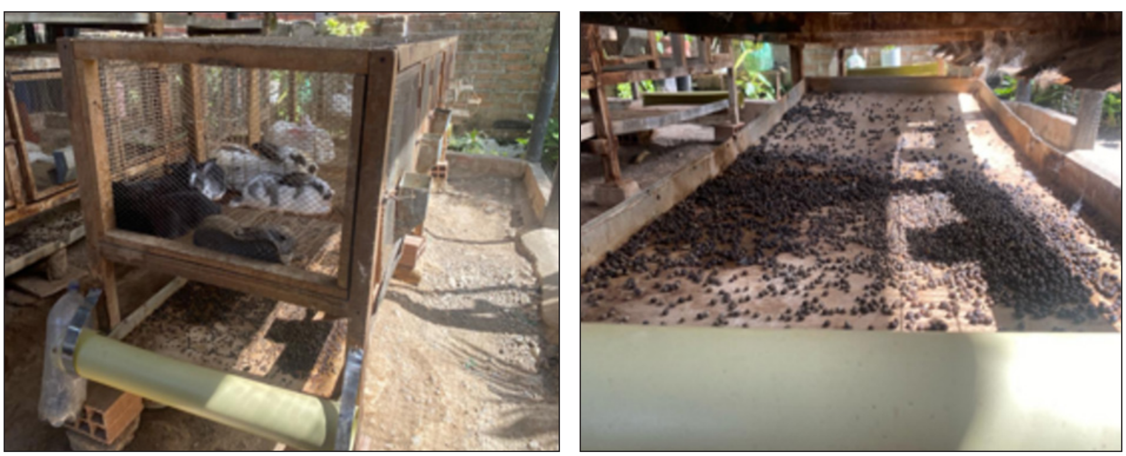
Method. A complete enumeration method (Montgomery, 2017). Was used to analyze the data from different treatments. This involved measuring all individuals within each of the four experimental groups. By including every bird in the analysis, we were able to achieve greater precision due to improved nutritional control for each individual and complete data for each group. This allowed for robust comparisons between the groups and their respective treatments.

Phase one. Preparation of nutritional treatments. To ensure optimal nutrition, the feed was formulated based on established commercial standards for broiler chickens, such as those outlined by the National Research Council (NRC, 1994). The formulation considered essential components including crude protein, fat, moisture, fiber, and ash; this carefully balanced composition aimed to meet the specific nutritional needs of broiler chickens at different stages.

Experimental procedure. Rabbit feces were subjected to treatment before being incorporated into the diets of Ross AP chickens at three levels: 10%, 30%, and 50%. A commercial poultry feed (Italcol brand) was used as a control treatment at 100%.

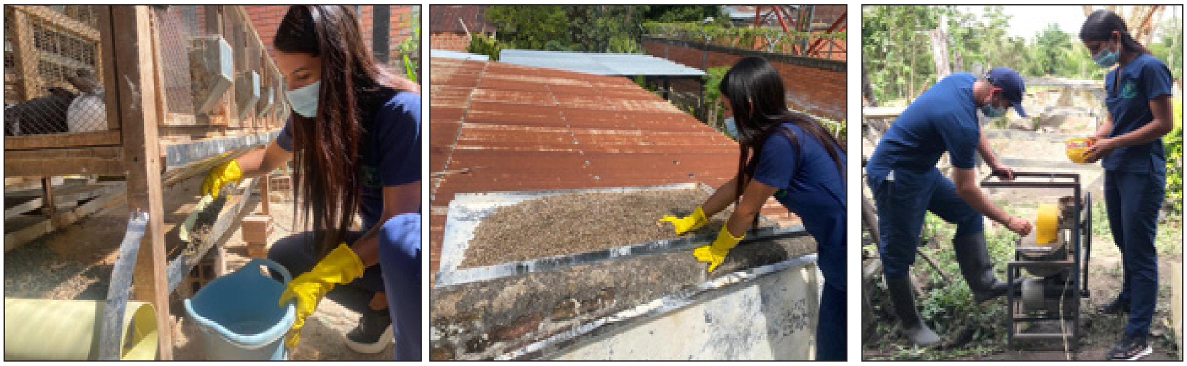
The formulated feed met the recommended crude protein requirements for Ross AP chickens during the starter, grower, and finisher phases: 23%, 21.5%, and 19.5%, respectively.

Preparation of the protein supplement. Rabbit feces were collected weekly from stainless steel trays (Figure A1, A2). The feces were manually extracted (Figure B1) and subsequently dehydrated (Figure B2). Any rabbit fur was removed before grinding the feces (Figure B3).



A1. Doe A2. Faces collector

Figure 1. Collection of rabbit feces.



B1. Manual Harvesting B2. Solar drying B3. Ground

Figure 2. Harvesting, drying, and grinding of rabbit manure.

Chemical analysis of rabbit feces. From the bibliographic sources (See Table 1), the chemical analysis of protein (Pc), fat (Gr), moisture (H), fiber (Fb), and ash (Cen) was determined.

Table 1. Chemical analysis of rabbit feces.

Author	Pc%	Gr%	H%	Fb%	Cen%
A (Brenes-Payá *et al.*, 1978)	20,3	1,4	--	47,4	6,2
B (Reyes-Rodríguez & Castillo-Ortiz, 1994)	20,22	1,15	11,3	14,25	23,8
C (Olvera, 2019)	22	0,5	--	44,7	13,6

Nutritional requirements. Ross AP broiler chickens require specific nutritional components to achieve optimal growth and reach a target live weight of 2.0-3.0 kg (4.4-7.7 lb) within 40 days. During the starter phase, their diet should contain 23% protein, 2975 kcal/kg of energy, 1.32% lysine, and 0.55% methionine. As they progress to the grower phase, the protein content can be reduced to 18%, while lysine and methionine requirements increase to 1.02% and 0.82%, respectively. Energy intake should remain at 3125 kcal/kg throughout the growth and finisher phases (Aviagen, 2022).

Nutritional contribution of the treatments in the starting stage. When the balance of the nutritional contribution according to the starting stage is made, the protein content (Pc) increases as the percentage of the supplement is added to the treatment. The component (Comp) and the contribution according to the value of the percentage as a contribution (Contrib) are taken as a starting point. On the other hand, the nutritional contribution of fiber (Fb) and ash (Cen) increases as the manure content increases in the treatment. Unlike fats (Gr) and moisture (H), which decrease as the percentage of treatment increases (see Table 2)

Table 2. Nutritional characteristics of the treatments.

Control group	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	100,00	2550	21	21	2	2	13	13	5	5	8	8
Manure	0,00			0		0		0	0	0	0	0
Total contribution	100,00			21		2,00		13,00		5,00		8,00
Treatment 1	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	90,00	2550	21	18,9	2	1,8	13	11,7	5	4,5	8	7,2
Manure	10,00	1500	22	2,2	0,5	0,05	11,3	1,13	44,7	4,47	13,6	1,36
Total contribution	100,00			21,1		1,85		12,83		8,97		8,56
Treatment 2	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	70,00	2550	21	14,7	2	1,4	13	9,1	5	3,5	8	5,6
Manure	30,00	1500	22	6,6	0,5	0,15	11,3	3,39	44,7	13,41	13,6	4,08
Total contribution	100,00			21,3		1,55		12,49		16,91		9,68
Treatment 3	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	44,7+D10:M10	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	50,00	2550	21	10,5	2	1	13	6,5	5	2,5	8	4
Manure	50,00	1500	22	11	0,5	0,25	11,3	5,65	44,7	22,35	13,6	6,8
Total contribution	100,00			21,5		1,25		12,15		24,85		10,80

Nutritional sharing of treatments in the growth and fattening stage. The nutritional contribution balance shows that the contents of (H), (Fb), and (Cen) remain the same as in the previous table. The difference in the contributions lies in the increased protein content, which rises from 18% in the control to 20% due to the manure content. Conversely, the fats for the growth and fattening stage are lower, ranging from 2.5% to 1.5% (see Table 3).

Table 3. Nutritional sharing of treatments –to growing and fattening stage.

Control group	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	100,00	2550	18	18	2,5	2,5	13	13	5	5	8	8
Manure	0,00			0		0		0	0	0	0	0
Total contribution	100,00			18		2,50		13,00		5,00		8,00
Treatment 1	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	90,00	2550	18	16,2	2,5	2,25	13	11,7	5	4,5	8	7,2
Manure	10,00	1500	22	2,2	0,5	0,05	11,3	1,13	44,7	4,47	13,6	1,36
Total contribution	100,00			18,4		2,30		12,83		8,97		8,56

Treatment 2	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	70,00	2550	18	12,6	2,5	1,75	13	9,1	5	3,5	8	5,6
Manure	30,00	1500	22	6,6	0,5	0,15	11,3	3,39	44,7	13,41	13,6	4,08
Total contribution	100,00			19,2		1,90		12,49		16,91		9,68
Treatment 3	Cant	$ / Kg.	Pc%		Gr%		H%		Fb%		Cen%	
			Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.	Comp.	Contrib.
Balanced feed	50,00	2550	18	9	2,5	1,25	13	6,5	5	2,5	8	4
Manure	50,00	1500	22	11	0,5	0,25	11,3	5,65	44,7	22,35	13,6	6,8
Total contribution	100,00			20		1,50		12,15		24,85		10,80

Phase Two: Temperature and Humidity Index (THI) and Thermal Comfort. To assess the impact of environmental conditions on weight gain, we compared the observed weight gain data to the Temperature and Humidity Index (THI), a metric developed by Thom (Sánchez et al., 2021). THI is a measure of the combined effect of temperature and humidity on human and animal comfort

$$THI=(1.8*ta) + 32- (0.55- 0.55*hr) + (1.8*ta-26)$$

ta= ambient temperature(°C)
hr= relative humidity

To assess the impact of treatments on broiler thermal comfort and weight gain, the Temperature and Humidity Index (THI) was calculated using the provided equation. A THI below 70 indicates a normal range with potential physiological and welfare risks, while a THI between 70 and 79 suggests low-level heat stress. Higher THI values (79-83) indicate moderate heat stress and values exceeding 84 indicate a danger zone with significant health risks (Ruíz et al., 2023).

Phase three - Descriptive statistical analysis. In phase three, a descriptive statistical analysis was conducted, where the average weight gain for each treatment was recorded. A one-way ANOVA was then performed to assess whether there were significant differences between the treatments. If significant differences were detected, a Tukey's HSD test was applied to pinpoint which specific treatments varied. The ANOVA results were further complemented by the Tukey analysis to identify the treatments that differed from one another.

RESULTS AND DISCUSSION

Chemical analysis of rabbit feces. Rabbit feces have been shown to contain a variety of nutrients, including protein, fiber, minerals, and vitamins. The exact composition of rabbit feces can vary depending on the diet of the rabbit and other factors. One study found that rabbit feces are composed of 20.3% Pb, 1.4% EE, 24.7% Fb, and 8.2% ash (Brenes-Payá et al., 1978). The amino acid content of rabbit feces is 0.6% lysine (Lis) and 0.13% methionine (Met) (Brenes-Payá et al., 1978). Another study found that rabbit feces contain 22% protein, 13.6% ash, 44.7% fiber, 0.5% EE, 3932.2% cellulose, 2.4% lipids, and 10.8% minerals (Olvera, 2019). Protein contents can reach 50% in rabbit feces (Olvera, 2019). Finally, a third study found that rabbit feces contain 17% protein, 30% Fb, and 38 ppm vitamin B (Romero, 2008).

Nutritional contribution. Nutritional analysis revealed that the Italcol brand while providing a protein content of 21%, fell slightly short of the recommended minimum of 23% crude protein for Ross AP broiler chickens during the starter phase. However, it's important to note that protein levels in commercial feeds can vary depending on specific formulations and intended uses. As the proportion of rabbit manure (RM) in the treatments increased, the overall protein content rose, reaching 21.5% in T3. This suggests that RM could be a valuable supplement to enhance the protein content of broiler diets.

Table 4. Protein intake according to growth and requirement for Ross Ap breeds.

Stage	control group (%)	T1(%)	T2(%)	T3(%)	T Recommended Breed Ross Ap(%)
Start-up stage	21	21,1	21,3	21,5	23
Growth stage	18	18,4	19,2	20	18

During the grower phase (45 days), Ross AP broiler chickens require a minimum of 18% crude protein in their diet. While the control treatment provided this level, incorporating rabbit manure (RM) into the diet gradually increased the protein content. The highest protein level was observed in Treatment 3 (50% RM), reaching 20%. Excessive protein intake can lead to increased abdominal fat deposition in poultry, while low protein levels can negatively impact the levels of non-essential amino acids like glycine and serine. Therefore, maintaining a balanced protein intake is crucial for optimizing broiler development and overall health (Torres, 2018; Vargas, 2024; Gonzales-Beleño & Vergel-Vega et al., 2022).

Protein: Excess protein in broiler diets does not always translate to improved production efficiency. Studies have shown that increasing crude protein levels beyond 21.4% in the starter phase and 18.5% in the finisher phase does not significantly enhance production performance, carcass characteristics, or meat quality (Infante-Rodríguez et al., 2020). Surprisingly, excessive protein intake had no noticeable impact on broiler weight gain, highlighting the importance of tailoring feeding practices to local conditions. Providing excess protein in the diet can be unnecessary and may even lead to increased feed costs for poultry growers.

Maintaining the right balance between energy and protein is essential in broiler nutrition. Although raising both energy and protein levels can be advantageous, too much protein doesn't always translate into better economic outcomes (Quishpe, 2006). Protein is a valuable nutrient, but relying on it as a primary energy source can be inefficient. Moreover, excessive protein intake leads to higher nitrogen excretion, which can negatively impact the environment.

Fiber is another essential component of broiler diets, but its inclusion must be carefully balanced. Excessive fiber can dilute the energy density of the diet, reduce the digestibility of other nutrients, and negatively impact growth performance (Bortoluzzi et al., 2023). Finding the right balance of fiber is crucial for optimizing intestinal health and broiler performance.

The effects of different fiber types and enzyme supplementation on broiler physiology were investigated in a recent study (Sánchez et al., 2021). The results highlighted the complex interactions between these factors and emphasized the need to tailor feeding strategies to the specific needs of different broiler species.

The study area, Sartenejal, experienced record-breaking high temperatures during December 2023 and January 2024, reaching 40°C at midday (Figure 3) (Caicedo, 2024). This extreme heat event significantly increased the Temperature-Humidity Index (THI), exceeding established comfort zones for poultry. As a result, the broilers faced elevated heat stress, which negatively impacted their weight gain.

The THI values recorded during this period exceeded the normal range (less than 70), indicating a need for increased attention to bird welfare. High THI values can lead to physiological and welfare issues in poultry, including reduced feed intake, decreased growth rates, and increased mortality (Sanchez, 2021). The Sartenejal region, usually known for its frequent rainfall and moderate temperatures ranging from 24°C to 28°C was unprepared for the extreme heat it experienced (NOAA, 2024).

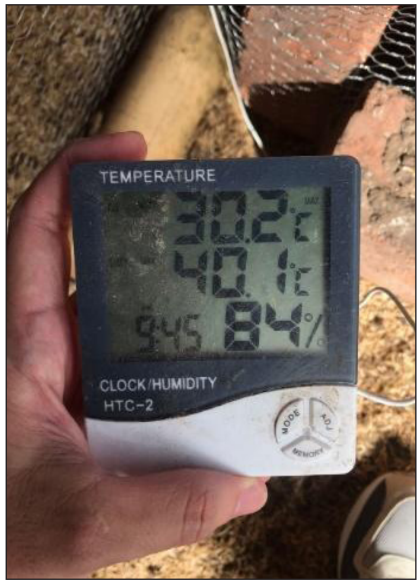


Figure 3. Photographic evidence of
maximum recorded temperature, January 2024.

The THI index, a measure of thermal stress, remained within the 'alert' range (70-79) from week 2 to week 7. This indicates that the broilers required increased attention during this period. Specific management practices included ensuring adequate ventilation, providing fresh water, and regularly monitoring bird health through plumage inspection, fecal color, and weight gain. The observed weight gain data aligns with the THI index, demonstrating its effectiveness in assessing thermal stress and guiding appropriate management interventions.

Table 5. Temperature and Humidity Index (THI)

Weeks	THI	control group (g)	T1(g)	T2(g)	T3(g)
Week 1	79,93	128,09	142,09	136,91	133,82
Week 2	98,98	246,58	248,79	214,45	209,67
Week 3	88,97	510,52	483,94	396,48	351,82
Week 4	91,03	868,73	812,70	647,70	546,39
Week 5	95,12	1339,14	1295,02	993,61	831,95
Week 6	94,6936643	2024,09	1872,55	1416,00	1236,18
Week 7	98,9446467	2793,30	2471,18	2017,37	1651,27

During the dry season in the Sartenejal region, the Temperature-Humidity Index (THI) had a notable effect on broiler weight gain. As illustrated in Table 5, the control group (0% rabbit manure) showed an average weight gain of 128.09 grams, while Treatment 1 (10% rabbit manure) achieved a slightly higher gain of 142.09 grams. However, a clear trend emerged when comparing the treatments: as the proportion of rabbit manure in the diet increased, weight gain generally decreased, especially in treatments where the THI index fell within the “alert” range (70-79).

The Control group, with a THI index of 98.9, required an additional week to reach the target weight of 2700 grams. In contrast, the control group with 10% rabbit manure inclusion achieved an average weight gain of 2471.3 grams in the seventh week, despite operating under the same ‘Danger’ THI conditions.

The THI index is a valuable tool for assessing thermal comfort in poultry. A THI value below 22 indicates a comfortable environment for Ross AP broilers, with a temperature of 15°C and relative humidity of 50%. However, as THI values increase, birds experience increasing levels of heat stress. A THI between 24.6 and 30.4 indicates moderate heat stress, while values above 30.4 may pose significant health risks.

Descriptive statistical analysis of weight gains and its relationship to treatments. To evaluate the impact of different feed treatments on broiler weight gain, a descriptive statistical analysis was conducted. One-way ANOVA was used to determine if there were significant differences between the treatments. Tukey’s multiple comparisons test was then applied to identify which specific treatments differed from each other.

The ANOVA analysis indicated significant differences in weight gain among the treatments ($F=11.3047$, $p=0.000017$). Tukey’s HSD test further clarified these differences, highlighting key findings. Treatment 2 (30% rabbit manure) resulted in significantly lower weight gain compared to Treatment 1 (10% rabbit manure) with a mean difference of -36.82 grams ($p=0.0145$). Similarly, Treatment 3 (50% rabbit manure) showed a substantial reduction in weight gain compared to Treatment 1, with a mean difference of -47.09 grams ($p=0.0012$). Interestingly, there was no significant difference between Treatment 1 and the control group (0% rabbit manure).

Further comparisons showed that Treatment 2 led to significantly lower weight gain than the control group, with a mean difference of -46.18 grams ($p=0.0015$), while Treatment 3 exhibited the most pronounced reduction, yielding a mean difference of -56.45 grams compared to the control group ($p=0.0001$). There was no significant difference in weight gain between Treatments 2 and 3, indicating that higher levels of rabbit manure (30% and 50%) consistently hampered growth.

CONCLUSIONS

This study highlights the significant impact of nutritional treatments on broiler weight gain during the starter phase. Italcol feed, with a protein content of 21%, falls short of the recommended 23% crude protein (CP) requirement for Ross AP broiler chickens, suggesting that a nutritional supplement may be needed to bridge this gap. In contrast, the experimental treatments (T1, T2, and T3) all exceeded the required CP levels, with Treatment T1, containing 18.4% CP, proving to be the most effective in promoting weight gain.

High levels of the Temperature-Humidity Index (THI) and increased dietary protein and fiber can negatively impact broiler weight gain. The control group, experiencing a lower THI, achieved the target weight of 2700 grams, while the 50% rabbit manure treatment (T3) resulted in significantly lower weight gain. Treatment T1 (10% rabbit manure) showed no significant difference from the control group, demonstrating that it is as effective as the standard diet in supporting broiler growth. However, Treatments T2 (30% rabbit manure) and T3 (50% rabbit manure) led to significantly lower weight gains compared to both the control group and T1, indicating their reduced effectiveness.

Based on these findings, Treatment T1 appears to be the most suitable for promoting broiler weight gain, while Treatments T2 and T3 may not be recommended due to their lower effectiveness.

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BIBLIOGRAPHIC REFERENCES

Aviagen. (2022). Pollo Ross: Especificaciones nutricionales. https://acortar.link/fZLuye

Aquarium. (2021). *It was actually full of nutrients! I looked into the poop situation of rabbits and koalas.* https://sunshineaquarium-onlineshopwp.jp/post-1917/

Asmar, S. (2021). Las causas detrás del alto costo en el primer semestre de concentrados para animales. https://www.agronegocios.co/agricultura/las-causas-detras-del-alto-costo-en-el-primer-semestre-de-concentrados-para-animales-3201392

Bortoluzzi, C.; Perez-Calvo, E.; Olsen, P. B.; van-der-Vaart, S.; van-Eerden, E.; Schmeisser, J.; Eising, I.; Segobola, P.; Sorbara, J. O. B. (2023). Effect of microbial muramidase supplementation in diets formulated with different fiber profiles for broiler chickens raised under various coccidiosis management programs. *Poultry Science*. 102(10): 102955. https://doi.org/10.1016/j.psj.2023.102955

Brenes-Payá, A.; Brenes-Payá, J.; Pontes-Pontes, M. (1978). Requerimientos nutritivos del conejo. *Le Courrier Avicole*. 3(13): 65-75. https://dialnet.unirioja.es/servlet/articulo?codigo=2915596

Caicedo, E. (2024). Este podría ser el enero más caliente de los últimos 30 años en Colombia: Ideam. https://www.eltiempo.com/vida/medio-ambiente/ideam-este-podria-ser-el-enero-mas-caliente-en-30-anos-en-colombia-848402

Cascavita, J. D.; Colorado, L. C. (2023). Análisis de producción del concentrado avícola en global feed nutrition. https://repository.universidadean.edu.co/bitstream/handle/10882/12883/CascavitaJulian2023.pdf?sequence=1;isAllowed=y

Castillo-Rodríguez, S. P.; Aguilar-Reyes, J. M.; Lucero-Magaña, F. A.; Martínez-González, J. C. (2007). Sustitución de alimento comercial por excretas en la dieta de conejos en crecimiento. *Avances en investigación agropecuaria*. 11(1): 41-48.

Cenicafe. (2024). Boletín Diario. Agroclima. https://agroclima.cenicafe.org/boletin-diario

Delgado, E.; Orozco, Y.; Uribe, P. (2013). Comportamiento productivo de pollos alimentados a base de harina de plátano considerando la relación beneficio costo. *Zootecnia Tropical*. 31(4): 279-290.

Dorado, S.; Habibi, M. F.; Gerrits, W. J. J.; de-Vries, S. (2024). Effect of adding soluble viscous fibers to diets containing coarse and finely ground insoluble fibers on digesta transit behavior and nutrient digestibility in broiler chickens. *Poultry Science*. 103(4): 103487. https://doi.org/10.1016/j.psj.2024.103487

García-Sánchez, A. A.; Mejía-Haro, I.; Silos-Espino, H.; Martínez-Mireles, J. M.; Aréchiga-Flores, C. F.; Silva-Ramos, J. M. (2023). Variables productivas y digestibilidad en conejos alimentados con diferente nivel de vaina de Prosopis laevigata en la dieta. *Acta universitaria*. 33: 1-14. https://doi.org/10.15174/au.2023.3561

García-Vázquez, L.; Fernández-Vargas, G.; Ocampo-López, J.; Ayala-Martínez, M.; Hernández-Aco, R.; Zepeda-Bastida, A. (2021). Relación de buenas prácticas productivas/disminución de parásitos en granjas cunícolas del Valle de Tulancingo. *Abanico Agroforestal*. 3. https://doi.org/10.37114/abaagrof/2021.8

Garçon, C. J. J.; Ellis, J. L.; Powell, C. D.; Navarro-Villa, A.; Garcia Ruiz, A. I.; France, J.; de-Vries, S. (2023). A dynamic model to measure retention of solid and liquid digesta fractions in chickens fed diets with differing fiber sources. *animal*, 17(7): 100867. https://doi.org/10.1016/j.animal.2023.100867

Godoy, G. L.; Rodrigues, B. N.; Agilar, J. C.; Biselo, V.; Brutti, D. D.; Maysonnave, G. S.; Stefanello, C. (2024). Efectos de los taninos *de Acacia mearnsii* sobre el crecimiento, la dermatitis plantar, la digestibilidad de los nutrientes, la permeabilidad intestinal y la calidad de la carne de pollos de engorde. *Animal Feed Science and Technology*. 308: 115875. https://doi.org/10.1016/j.anifeedsci.2024.115875

Gonzales-Beleño, M. J.; Vergel-Vega, J. C. (2022). Rendimiento productivo en pollos de engorde alimentados a base de harina de zapallo. https://doi.org/10.13140/RG.2.2.20284.31367

Gou, Z.; Fan, Q.; Li, L.; Wang, Y.; Lin, X.; Cui, X.; Ye, J.; Ding, F.; Cheng, Z.; Abouelezz, K.; Jiang, S. (2021). High dietary copper induces oxidative stress and leads to decreased egg quality and reproductive performance of Chinese Yellow broiler breeder hens. *Poultry Science*. 100(3): 100779. https://doi.org/10.1016/j.psj.2020.10.033

Infante-Rodríguez, F.; Domínguez-Muñoz, M. Á.; Montaño-Gómez, M. F.; Hume, M. E.; Anderson, R. C.; Manríquez-Núñez, O. M.; López-Acevedo, E. A.; Bautista-Martínez, Y.; Salinas-Chavira, J. (2020). 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. *Nova scientia*. 12(25): 00029. https://doi.org/10.21640/ns.v12i25.2585

Jalabe-Lagos, L.; Meneses-Prado, D. (2021). Suplementación con Gliricidia sepium (Matarratón) y Leucaena leucocephala (Leucaena) en la Alimentación de Conejos. https://doi.org/10.13140/RG.2.2.25859.43046

Lannuzel, C.; Smith, A.; Mary, A. L.; Della Pia, E. A.; Kabel, M. A.; de Vries, S. (2022). Improving fiber utilization from rapeseed and sunflower seed meals to substitute soybean meal in pig and chicken diets: A review. *Animal Feed Science and Technology*. 285: 115213. https://doi.org/10.1016/j.anifeedsci.2022.115213

Lin, Y.; Lourenco, J. M.; Olukosi, O. A. (2023). Efectos de la xilanasa, proteasa y xilooligosacáridos sobre el rendimiento del crecimiento, la utilización de nutrientes, los ácidos grasos de cadena corta y la microbiota en pollos de engorde desafiados por *Eimeria alimentados con una dieta rica en fibra*. *Animal Nutrition*. 15: 430-442. https://doi.org/10.1016/j.aninu.2023.08.009

Londok, J. J. M. R.; Rompis, J. E. G. (2021). Dressing percentage, giblet and abdominal fat of broiler chickens given Orthosiphon stamineus Benth leave juice in drinking water. *IOP Conference Series: Earth and Environmental Science*. 902(1): 012046. https://doi.org/10.1088/1755-1315/902/1/012046

Melo, J. M.; Torres, J. O. S.; Malamba, F. D. M. (2022). Sistemas de producción de conejos, características fisiológicas y alternativas para la alimentación / Rabbit production systems, Physiological characteristics and alternatives for feeding. *Universidad; ciencia*. 11(3): 82-97.

Mindiola, Y. P.; Villafaña-Zalabata, M. B.; Gamez-Baquero, Y. P. (2017). *Evaluación de 4 tipos de dietas en pollos de engorde de la línea Broiler ross, utilizando 3 líneas de concentrado de diferentes casas comerciales y un alimento hecho a base de maíz (Zea mays) y Leucaena (Leucaena leucocephala), con el fin de* *determinar la mejor dieta en cada uno de los tiempos.* http://repository.unad.edu.co/handle/10596/13523

Montgomery, D. C. (2017). *Design and analysis of experiments*. 9th ed. Hoboken, NJ: John Wiley & Sons, Inc.

National Research Council. (1994). Nutrient requirements of poultry, (9th ed). National Academies Press.

NOAA. (2024). Colombia: Perspectivas de impacto: Afectaciones segunda temporada de lluvias (oct-nov-dic) del 2023 y evolución de primera temporada seca (ene-feb-mar) del 2024 - Colombia. https://acortar.link/NHISBD

Olvera, E. R. (2019). Evaluación del comportamiento productivo y de la presencia de kafirinas en cecotrofos y heces duras en conejos en engorda alimentados con sorgo y diferentes niveles de fibra detergente neutro. http://ri-ng.uaq.mx/handle/123456789/1763

Quishpe, G. J. (2006). Factores que afectan el consumo de alimento en pollos de engorde y postura. https://bdigital.zamorano.edu/server/api/core/bitstreams/eb4e10d9-bf90-4a47-8171-14f048cdfa0e/content

Reyes-Rodríguez, F. J.; Castillo-Ortiz, E. (1994). Uso de excretas de conejo, cerdo, bovino, pollo y gallina en la dieta de ovinos. http://repositorio.cucba.udg.mx:8080/xmlui/bitstream/handle/123456789/3529/Rodriguez_Flores_Jose_Reyes.pdf?sequence=1

Romero, C. (2008). La importancia de la cecotrofia en el conejo. *Boletin de Cunicultura.* 53(156): 56-56.

Rubio, J. A.; Diaz-Vargas, M.; Duque-Ramirez, C. F. (2023). Digestibilidad de dietas con pulpa cítrica deshidratada para conejos en etapa de engorde. *Revista de Investigaciones Veterinarias del Perú*. 34(1): e22962. https://doi.org/10.15381/rivep.v34i1.22962

Ruíz, P. J.; Osorio-Hernández, R.; Ruíz Ramirez, P. J.; Osorio-Hernández, R. (2023). Propuesta metodológica para el análisis de confort térmico animal en zonas apartadas de Colombia. *Ingeniería*. 33(1): 34-47.

Saeed, M.; Kamboh, A. A.; Huayou, C. (2024). Promising future of citrus waste into fermented high-quality bio-feed in the poultry nutrition and safe environment. *Poultry Science*. 103(4): 103549. https://doi.org/10.1016/j.psj.2024.103549

Sánchez, D.; Valera-Rojas, M.; Casasola-Torres, R.; Gutiérrez-Borroto, O.; Mireles-Flores, S. (2021). Atenuación del estrés calórico en pollos con la suplementación de un producto de cromo orgánico. *Revista colombiana de ciencia animal recia*. 13(1): 18-26. https://doi.org/10.24188/recia.v13.n1.2021.792

Sanchez, J.; Barbut, S.; Patterson, R.; Kiarie, E. G. (2021). Impact of fiber on growth, plasma, gastrointestinal and excreta attributes in broiler chickens and turkey poults fed corn- or wheat-based diets with or without multienzyme supplement. *Poultry Science*. 100(8): 101219. https://doi.org/10.1016/j.psj.2021.101219

Santos-Ricalde, R.; Segura-Correa, J.; Gutierrez-Ruiz, E.; Aguilar-Pérez, C. (2023). Si el conejo, Oryctolagus cuniculus, es monogástrico ¿Por qué es importante que consuma fibra? *Bioagrociencias*. 16(1): 8. http://dx.doi.org/10.56369/BAC.4960

Saragih, H. T. S. S. G.; Salsabila, N.; Deliaputri, R.; Firdaus, A. B. I.; Kurnianto, H. (2023). Growth morphology of the gastrointestinal tract, pectoralis thoracicus muscle, lymphoid organ and visceral index of kampong chicken. *Journal of the Saudi Society of Agricultural Sciences*. 23(1): 34-41. https://doi.org/10.1016/j.jssas.2023.08.005

Sarzosa, M.; Gabriel, E.; Calle, O.; Stalin, R.; Valdivieso, S.; Benjamín, M. (2022). *Efecto del biol de estiércol de conejo en el desarrollo del forraje verde hidropónico de maíz*. https://www.dspace.uce.edu.ec/server/api/core/bitstreams/d6a450bf-4955-4d9e-b84f-6ed861af75f0/content

Sevim, Ö.; Ahsan, U.; Tatlı, O.; Kuter, E.; Khamseh, E. K.; Reman-Temiz, A.; Sayın-Özdemir, Ö.; Aydın, A. K.; Özsoy, B.; Köksal, B. H.; Cengiz, Ö.; Önol, A. G. (2021). Effect of high stocking density and dietary nano-zinc on growth performance, carcass yield, meat quality, feathering score, and footpad dermatitis in broiler chickens. *Livestock Science*. 253: 104727. https://doi.org/10.1016/j.livsci.2021.104727

Torres, D. M. (2018). Exigencias nutricionales de proteína bruta y energía metabolizable para pollos de engorde. *Revista de Investigación Agraria y Ambiental*. 9(1): 106-113. https://doi.org/10.22490/21456453.2052

Usakura. (2022). The Wonder of Appendicular Feces. The Secret of Power. https://n9.cl/0ctcyj

Vargas, L. (2024). Efectos de diferentes suministros dietéticos de treonina y glicina en pollos de engorde alimentados con dietas bajas en proteínas. https://acortar.link/DX0YiK