Original Article

Performances and Lipidic Profile of Guinea Pigs (*Cavia Porcellus*) Fed with *Curcuma Longa*

Santiago Alexander Guamán-Rivera[1]*, Sandra Patricia Jácome-Tamayo[2], Julio Cesar Benavides Lara[1], Antonio Pompeyo Guacapiña-Viteri[3], Dina Maricela Veloz-Veloz[4]

[1]Escuela Superior Politécnica de Chimborazo, (ESPOCH) Sede Orellana, El Coca 220150, Ecuador.
Email: santiagoa.guaman@espoch.edu.ec
[2]Escuela Superior Politécnica de Chimborazo, (ESPOCH) Sede Morona Santiago, Ecuador.
Email: sandra.jacome@espoch.edu.ec
[1]Escuela Superior Politécnica de Chimborazo, (ESPOCH) Sede Orellana, El Coca 220150, Ecuador.
Email: jbenavides@espoch.edu.ec
[3]Instituto Nacional de Investigaciones Agropecuarias INIAP, Estación Experimental Santa Catalina Programa de Ganadería y Pastos, Panamericana. Sur, km 1, sector Cutuglagua, Código postal 171107.
Email: antonio.guacapina@iniap.gob.ec
[4]Carrera de Medicina Veterinaria, Facultad de Ciencias Agropecuarias y Recursos Naturales (CAREN). Universidad Técnica de Cotopaxi, Latacunga, Ecuador.
Email: dina.veloz9302@utc.edu.ec

Abstract

Background: The South American guinea pig, a rodent species, has been domesticated and is considered suitable for human food in various parts of the world. In Ecuador, Cavia porcellus, which was initially domesticated by indigenous populations, is frequently utilized for ensuring food security due to its meat's resemblance to that of rabbit or chicken. Furthermore, small-scale farmers in Ecuador utilise indigenous food resources as supplements due to their capacity to offer bioactive components that yield several advantages for organic reactions. The primary application of Curcuma longa (C.longa) meal is as a feed supplement for Cavia porcellus. Nevertheless, certain investigations have also documented productive, metabolic, or immunological responses. Hence, the objective of this study was to assess the impact of dietary supplementation with C. longa on guinea pigs. **Methodology:** In this study, a completely randomized design was used to assign 220 mice to four treatments: "Control", "T1", "T2", and "T3". The assignment of animals to treatments was done randomly. The initial treatment, referred to as "Control", consisted of a meal comprising 60% concentrate feed. The second treatment, T1, consisted of 0.60% C. longa, T2 consisted of 1.30% C. longa, and T3 consisted of 2.30% C. longa. **Results:** the amount of feed consumed did not vary amongst the different treatments over the course of the experiment (125 ± 13 g/day, $p = 0.32$). Nevertheless, the inclusion of 1.30% of C. longa (T2) led to a significant increase in the final body weight ($p < 0.001$), while T3 exhibited a higher feed conversion ratio ($p < 0.001$). Therefore, an observation was made about the likelihood of carcass surrender, with a measured tendency ($p = 0.08$). The T2 group had a greater percentage (77%) compared to the T1 group (72%; $p = 0.03$) and the T3 group (73%; $p = 0.04$). Furthermore, the difference was even more significant when compared to the Control treatment group (63%; $p = 0.001$). Regarding expansion, the serum lipid concentration was significantly lower in the T2 therapy compared to T1, T3, and the Control group ($p = 0.001$ to 0.023). **Conclusions:** Thus, including C. longa as a nutritional supplement in animal production appears to be a beneficial alternative to antibiotics, also reducing the production of high carbon footprint products. Similarly, we determined that the inclusion of C. longa flour at a concentration of 1.30% as a dietary supplement effectively regulates the levels of lipids in the blood serum of Guinea pigs. These promising results allow for a comprehensive and advanced range of support studies at immunological levels to validate the bioactive characteristics of C. longa.

Keywords: Bioactive Compounds, Organic Responses, Security Food, Small Farmers.

Introduction

The guinea pig, scientifically known as Cavia porcellus, is a rodent that has been domesticated in the highlands of Peru, Ecuador, Colombia, and Bolivia for a minimum of 7000 years.

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Address for Correspondence: Escuela Superior Politécnica de Chimborazo, (ESPOCH) Sede Orellana, El Coca 220150, Ecuador.
Email: santiagoa.guaman@espoch.edu.ec

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[1] The flesh, which has resemblance in both appearance and flavour to rabbit or chicken meat, has been a dietary staple for indigenous populations for millennia.[2] Moreover, the Cavia porcellus, found in South America, plays a crucial role in providing a substantial protein source for rural smallholders. This contributes to their food security and also helps in mitigating malnutrition.[3] In Ecuador, the traditional-family breeding system in the Andean area extensively utilises Cavia porcellus, but with little technological advancements. Additionally, a qualitative investigation centred on small-scale farmers revealed that they typically rely on native foods rather than antibiotics for the purpose of cultivating animals for their own family food provision.[4] Despite this, Cavia porcellus exhibits a high reproductive capacity and demonstrates remarkable versatility in adapting to various housing and management methods.[5] Consequently, it plays a significant role in the culinary traditions of rural smallholders in this area.

The global practice of using antibiotics as a feed additive in animal production is widespread. This is done to manage and prevent diseases, as well as to enhance growth.[6-8] Van Boeckel *et al*.[9] reported that in 2010, around 63,151 tonnes of antibiotics were utilised in global food animal production. However, projections for 2030 indicate a potential increase of nearly 67% to reach 105,596 tonnes. Antimicrobial resistance (AMR) refers to the phenomenon where bacteria, viruses, fungi, and parasites lose their ability to be effectively treated by medications, as supported by multiple scientific findings.[10] Hence, antimicrobial resistance (AMR) has far-reaching implications for the well-being of humanity, leading to an estimated annual mortality of around 700,000 individuals.[11] O'Neill[12] predicts that by 2050, the number of deaths attributable to antimicrobial resistance (AMR) could increase to 10 million per year, resulting in an estimated economic burden of $100 trillion USD. The World Organisation for Animal Health[13] created a list of antibiotics that are prohibited for use in veterinary medicine. Additionally, the European Medicines Agency (EMA) changed the classification of antibiotics used in animals to encourage responsible usage.[14] These guidelines aim to mitigate antimicrobial resistance (AMR) and safeguard the efficacy of antibiotics for both people and other animals.

The United Nations (UN), in response to the challenges posed by armed conflict, social inequality, and climate change, put up a set of 17 sustainable development goals (SDGs) as a key component of the 2030 agenda for sustainable development. The SDGs represent a significant change towards a single agenda for sustainable development, following previous attempts to combine economic and social development with environmental sustainability.[15] While all Sustainable Development Goals (SDGs) are connected to animal production, SDG 12 specifically aims to guarantee sustainable consumption, and SDG 3 focuses on ensuring healthy lifestyles and fostering well-being for all individuals, regardless of age.[16] Additionally, it is crucial to note that consumers of animal products are increasingly seeking meat that is free from any traces of drugs. Consequently, there has been significant focus on local food resources because of their bioactive components that have the ability to regulate organic reactions even in little amounts.[17]

In light of the previously indicated situation, it is possible to utilise natural growth stimulants such as plant extracts to feed Cavia porcellus without any negative consequences. Curcuma longa is extensively utilised as a condiment, colouring agent, and is renowned for its therapeutic qualities.[18] The plant is a perennial herb with rhizomes, reaching a height of around 1.5 metres. It is found in tropical and subtropical locations worldwide.[17] The primary constituents of the rhizome are the non-volatile curcuminoids and the volatile oil.[18,19] Curcuminoids, including curcumin, de-methoxycurcumin, and bisdemethoxycurcumin, are polyphenolic derivatives of curcumin. They are non-toxic and have a diverse spectrum of biological activities and pharmacological properties.[20] Additionally, Curcuma longa is utilised in several animal species like rabbits,[21] poultry,[21-24] and rats.[23,25] There is a significant dearth of study utilising Cavia porcellus as a means to investigate performance, metabolic, and immunological responses. In Ecuador, although Curcuma longa is commonly consumed by rural smallholders, there have been limited studies conducted to investigate the potential of this local food, which is rich in antioxidants, as an alternative to antibiotics for promoting growth. To achieve this objective, we conducted an experiment using Cavia porcellus as an animal model. We evaluated the effects of various quantities of Curcuma longa flour on performance and lipid properties.

Materials and Methods

Ethical Issues

The animal care, lodging, and nourishment techniques were modified according to the guidelines set by the World Association for Animal Welfare in 2016 and the current Ecuadorian rules known as the Natural Law on Animal Welfare No. 56, published in the Official Gazette, Supplement 27, on July 3, 2017. However, this study did not need approval from an Animal Care and Use Committee because it did not involve animals used for scientific purposes as typically required by Mandate 2010/63/EU[26] [Art. 2.5], as practices unlikely to cause pain, suffering, distress or lasting harm equivalent to, or greater than, that caused by the insertion of a needle in accordance with proper veterinary practice].

Experimental Site

The climate in this locale is characterized by muggy tropical rainforest conditions.[27] The normal yearly precipitation is of around 2942 mm with a normal yearly temperature of 29.7 °C, and heights of around 275 m above sea level.

Processing of Curcuma Longa Flour

For this experiment, the *Curcuma longa* was harvested and sundried for seven days. From there on, it was ground into powder employing a pound process of strainer estimate 2 mm. The chemical examination of Curcuma longa is recorded in Table 1.

Table 1: Phytochemical Composition of Curcuma longa Flour (Values are Means + Standard Deviation of Three Determinations.

Phytochemicals	Composition (%)
Alkaloid	0.83 ± 0.02
Saponin	0.33 ± 0.02
tannin	1.01 ± 0.05
Sterol	0.03 ± 0.05
Hydrogen cyanide	0.75 ± 0.07
Flavenoid	0.29 ± 0.04
Phenol	0.04 ± 0.05

Animal Equipment and Housing

Two hundred and twenty guinea pigs, exclusively of male's gender with an average of body weight 320 ± 15 g were used and housed in individual cages, which provided of drinkers and feeders. The cages were composed of metal mesh measuring 62 × 50 × 37.5 cm. Besides this, all through the experiment, controlled environmental conditions (20 to 25°C; 16HL:8HO) were kept up.

Animal Experimental Diet

A total of 220 *Cavia porcellus* of four weeks of age were allocated into four treatments in a completely randomized design (Control, T1, T2 and T3 of Curcuma longa flour). At the first step, all animals were subjected to adaptation period (seven days) with a basal diet (Control) consisting of *Megathyrsus maximus* and concentrate (60:40). The experiment lasted twelve weeks. So, after adaptation, three experimental diets were formulated by adding *Curcuma longa* flour, as shown in Table 2.

Table 2: Composition of Experimental Diets.

Ingredients, %	Experimental Diets			
	Control	T1	T2	T3
Megathyrsus maximus	60.75	60.75	60.75	60.30
Ground yellow corn	11	11	10.5	10.0
Rice powder	8.0	8.0	7.8	7.8
Palma oil	0.50	0.5	0.5	0.5
Cane molasses	0.50	0.50	0.50	0.50
Soybean meal	18.75	18.15	18.15	18.10
Vit . and Min. premix[1]	0.50	0.50	0.5	0.5
Curcuma longa flour	0	0.60	1.30	2.30
Total	100	100	100	100
Calculated Composition				
Digestible energy, Mcal/kg	2.4	2.3	2.2	2.2
NDF, %	35	33	32	32
Crude protein, %	16	16	15	15

Measurement Data

Performance Responses and Economic Profit

Feed intake was daily recorded through a balance, capacity 2000 g ± 0.5 precision (GRAM FC, Madrid, Spain) whereas individual body weight (BW) was weekly recorded (GRAM FC, Madrid, Spain). The feed conversion ratios were calculated utilizing the data on body weight gain and feed intake.

Feed conversion ratio. FCR = feed intake (g)/ weight gain (g)

In contrast, for carcass yields, after *Cavia porcellus* were slaughtered, bloodless and scalded (60–70°C during 45–60 seconds). This comprised the body after removal the hair, the head (between the occipital bone and first cervical vertebra), the hand and the feet at carpo-metacarpal and tarso-metatarsal joints, respectively, and the viscera.[2] The carcass retains the skin, lateral portions of the diaphragm and the perirenal and pelvic fat depos-its. Finally, the economic profit was obtained between production costs and income.

Serum Lipid Concentration

For serum lipid concentration, five animals were randomly selected in each treatment. Blood samples were collected from ear vein in BD vacutainer (4 mL) without anticoagulant (BD Diagnostics, Franklin Lakes, NJ, USA) at one week prior to applicated treatments and at four, six, eight and twelve weeks after *Curcuma longa* supplementation before the morning feeding. The blood samples were allowed to rest during 24 h for the obtained serum and were stored at −20°C in 1.5 mL Eppendorf tubes until analysis. Then, through spectrophotometry method, HDL cholesterol and triglyceride were analysed as prescribed by the commercial kits.

Statistical Analysis

All statistical analysis were performed using the SAS version 9.1.3 (SAS Institute Inc., Cary, NC). Previously, all data were checked with a normality test (PROC UNIVARIATE). Thereafter, productive data were subjected to one-way analysis of variance (ANOVA) through general linear model (GLM). In contrast, the metabolic responses were treated by repeated measure PROC MIXED of SAS. Regression analyses were obtained with the PROC REG procedure. Differences between least squares means were determined with the PDIFF test of SAS. Significance was declared at $P < 0.05$ unless otherwise indicated.

Results

Productive Responses

The productive responses of *Cavia porcellus* subjected at different *Curcuma longa* levels, are shown in Table 3. No differences among treatments were observed when compared feed intake ($P = 0.32$: Table 3). The feed intake had a mean value of (124 ± 13 g/d, as indicated in Table 3). In the same way, initial BW did not differ when started experiment ($P = 0.60$) those averages were 355 ± 0.2 g of BW. Besides, previous to *Curcuma longa* levels ad-ministration, initial values of BW yielded a variation coefficient lower than 15%, which means that it remained homogeneous.

Table 3: Least Square Means of Productive Data When Cavia Porcellus Were Subjected Different Curcuma Longa Levels.

Items	Treatments[1]				SEM	*P* -Value
	Control	T1	T2	T3		Treatment
Feed intake, g/d	124	125	125	125	13	0.32
Initial body weight, g/d	356	357	353	354	0.2	0.60
Final body weight, g/d	498^{d}	595^{c}	698^{a}	644^{b}	1.7	0.001
Feed conversion ratio	3.6^{a}	3.1^{b}	2.7^{c}	2.4^{d}	0.10	0.001
Carcass yield, %	63^{z}	72^{y}	77^{x}	73^{y}	0.2	0.08

[1]Treatments; **Control**, same as adaptation; **T1**, Curcuma longa 0,60%; **T2**, Curcuma longa 1.30%; **T3,** Curcuma longa 2.30%; SEM, standard error of the means; $^{a-c}$ Means with different letter in the same row indicate statistics differences at $p < 0.05$; $^{x-z}$ Means with different letter in the same row indicate a statistics tendency at $P < 0.10$.

Final values of BW of *Cavia porcellus* after administration the different Curcuma longa levels, are shown in Table 3. The final values of BW differed when included Curcuma longa flour in diets of Cavia porcellus ($P < 0.001$). The T1 treatment, demonstrated higher BW values (698 ± 1.7, on average) than those observed in T3 (644 ± 1.7, on average) and T1 (595 ± 1.7, on average), respectively, which also differed between them (Table 3). Whereas, when compared to those of Control treatment, huge statistic differences were detected (498 ± 1.7 g, on average; $P = 0.03$ a 0.001). In addition, the BW data presented a lineal tendency, although not statistically significant ($P = 0.32$; Figure 1).

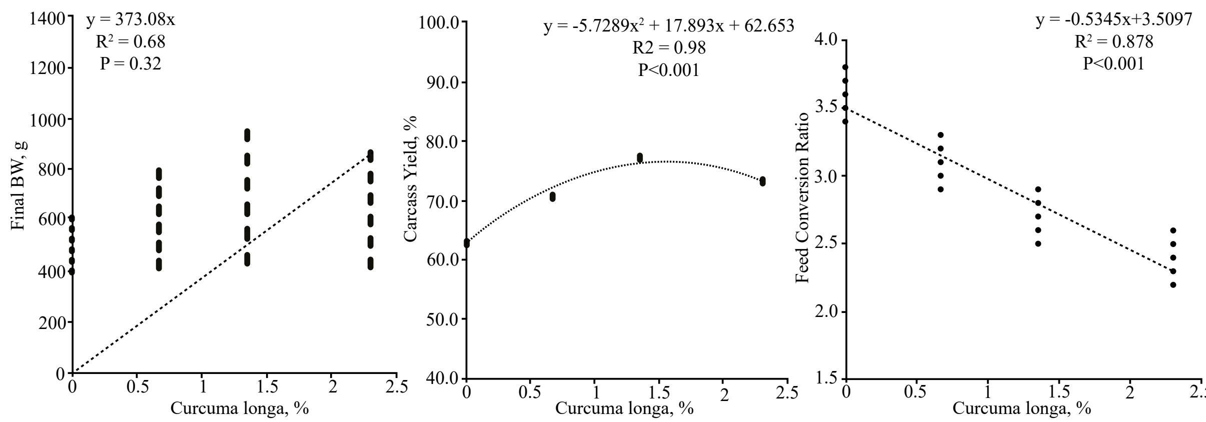

Figure 1: Regression Adjustment for Final BW, Carcass Yields and Feed Efficiency According to Different *Curcuma Longa* Levels.

As for feed conversion ratio, the T3 (2.4 ± 0.10%, on average; $P < 0.001$), T2 (2.7 ± 0.10%, on average; $P < 0.002$) and T1 (3.1 ± 0.10%, on average; $P < 0.004$) treatments had higher feed conversion than those observed in Control (3.6 ± 0.10%, on average; $P < 0.001$). Furthermore, the feed conversion ratio with regard to different *Curcuma longa* levels indicated an exponential adjustment ($P = 0.04$; Figure 2). In other words, the inclusion of 2.30% of *Curcuma longa* had highest feed conversion from a nutritional point of view. Consequently, it implies that there is no need of a high feed intake for achieving more BW.

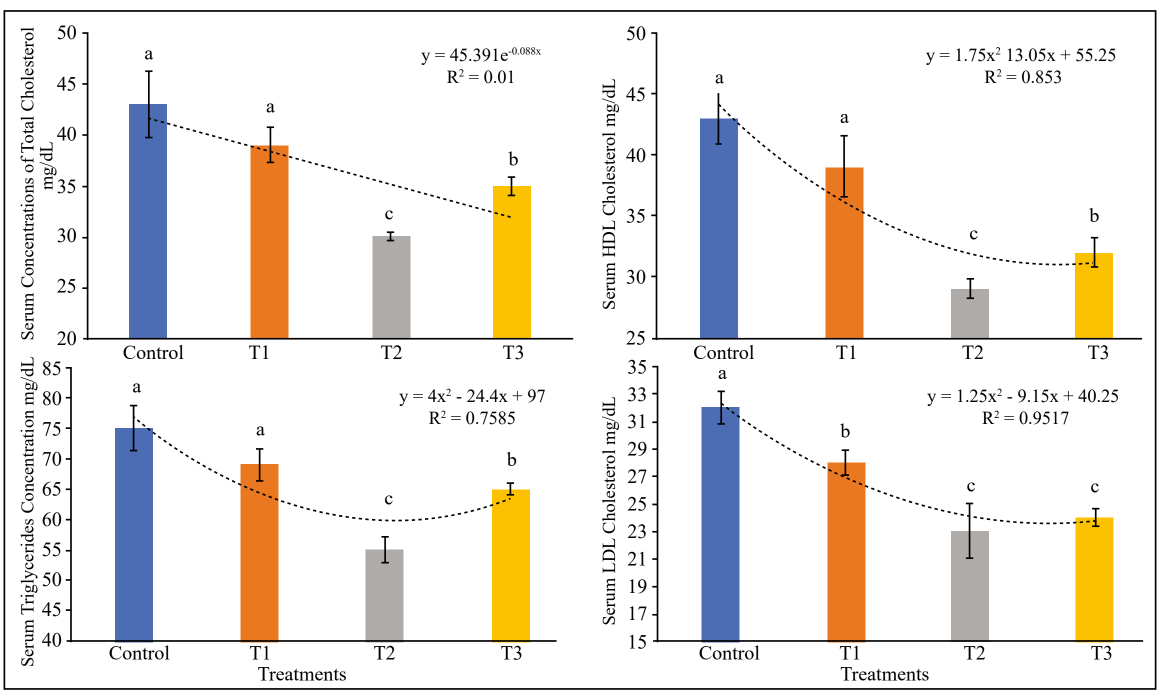

Figure 2: Effects of Incorporation Level of Curcuma Longa Flour on Serum Lipid Concentration; Values Represent an Average of 12 Weeks; a,b Means with Different Letter Differ at P < 0.05. Treatments; Control, Same as Adaptation; T1, Curcuma Longa 0,60%; T2, Curcuma Longa 1.30%; T3, Curcuma Longa 2.30%.

Despite of clear numerical and statistical differences in the feed conversion among treatments (Table 3), the carcass yields only demonstrated statistical tendences ($P = 0.08$; Table 3). The inclusion of 1.30% of Curcuma longa had higher carcass yields (77 ± 0.13%; $P < 0.001$) compared to T1 (72 ± 0.84%) and T3 (73 ± 0.17%). It is fundamental to highlight that, all above results described differed than those to obtained for Control treatment (63 ± 0.11%; $P < 0.001$). However, the regression analysis resulted that the carcass yield had a polynomial adjustment that has been statistically significant (Figure 1; r = 0.98). Based on our results, this work shows a potential line of research that has been little explored, due to the properties of *Curcuma longa* as a potential added nutritional substance to be included in the diets of *Cavia porcellus* by small producers. As for economic terms, the cost production by each animal did not differ $P < 0.42$; USD 1.54) due to *Curcuma longa* has been obtained from the own farms. However, analysing the economic profits, based on carcass yields, the current study demonstrated that the treatment T2 (1.30%; 5 USD/kg) had higher economic benefit than those obtained in Control (3 USD/kg) as well as for T1 and T3 which both obtained, on average 4 USD/kg.

Serum Lipid Concentration

Level effects of *Curcuma longa* flour incorporation on serum lipid concentration, are shown in Figure 2. Prior to treatment applications, initial values of total cholesterol, HDL, LDL and triglycerides did not have statistic differences ($P = 0.30$ to 0.75). Nevertheless, serum concentrations of total cholesterol, HDL, LDL and triglycerides dramatically de-creased ($P < 0.05$) with the inclusion of *Curcuma longa* flour in the diets over time (12 weeks). In addition, the highest relationships among HDL, LDL, triglycerides and Curcuma longa concentration yielded a high regression coefficient ($r^2 = 0.85$ for HDL; $r^2 = 0.85$ for LDL and $r^2 = 0.78$ for triglycerides), which allows a strong relation between lipids concentration and the rate of inclusion Curcuma longa in feed.

Discussion

The reproduction of animals will gradually be impacted by external factors. These incorporate increasing demands for animal products and combat supplies of raw materials, arising from the competition for natural resources and trade barriers. Simultaneously, there is a growing concern regarding the impact of nutrition on health, as well as the influence of production systems on animal welfare and the environment.[28] Amidst the global rise of antibiotic-resistant microorganisms, bioactive compounds (BC) are garnering considerable interest due to their potential to effectively eradicate bacterial cells. Therefore, the BC utilise a uniquely designed apparatus to integrate functional foods into the animal nutrition sector.[29] However, the effectiveness of a birth control method relies on its capacity to ensure solvency, stability, and bioavailability.

Plants of the Curcuma genus are becoming increasingly important worldwide as significant components in food and traditional remedies.[29] Curcuma longa, sometimes referred to as "turmeric" globally, is alternatively known as "kurkum" in Arabic and "haldi" in Hindi and Urdu. It is synonymous with C. domestica Valeton and C. brog Valeton. Turmeric is widely cultivated globally, yet its origin is in Southeast Asia.[30] A recent study conducted by Djoumessi-Tobou *et al.*[31] found that the addition of Curcuma longa as a dietary supplement in Cavia porcellus resulted in an increase in dry matter intake (DMI). In addition, numerous animal models and human investigations have demonstrated that curcumin is highly safe, even when administered at exceptionally high dosages.[32] Nevertheless, Djoumessi-Tobou *et al.*[31] reported that elevated concentrations (> 1%, Curcuma longa, in DM) had an impact on the dry matter intake (DMI). The observed reactions may be attributed, at least in part, to the presence of alkaloids in the spices, which could have caused a bitter flavour in the feed. In contrast, the limited solubility of curcuminoids in water and their quick metabolism have an impact on their bioavailability, as well as their distribution in tissues. These factors also contribute to the short half-life of curcuminoids.[32,33] Shoba *et al.*[34] conducted an experiment where they gave rats a dose of 2 g/kg of Curcuma longa orally. They found that the rats had a maximum serum concentration of 1.35 (0.23 µg/mL) at 0.83 hours. In contrast, when humans were given the same dose of Curcuma longa, the serum levels were either undetectable or extremely low (0.006 ± 0.005 µg/mL) at 1 hour.

In this study, it was found that adding Curcuma longa at a concentration of 1.30% in the diet, based on dry matter (DM), resulted in better performance outcomes compared to other concentrations (0.60% and 2.3%), with the exception of dry matter intake (DMI). Kiczorowska *et al.*[35] state that in monogastric animals, the gut mucosa serves as a protective barrier against infections from the environment. In order to combat infectious and possibly dangerous pathogens, a sophisticated system of lymphatic tissue known as GALT (gut-associated lymphoid tissue) has evolved in the intestines. As a result, when curcumin is added to feed, it is absorbed to some extent in the intestine. Additionally, a significant amount of the ingested curcumin reaches the cecum and colon, where a big number of native bacteria are present.[36] Curcuma longa possesses beneficial characteristics, including antioxidant, free radical scavenging, and immunological and metabolic response modulation.[7,19,28]

In Ecuador, Cavia porcellus is commonly used to ensure food security. These animals are fed a mixed diet of forage. In this context, Curcuma longa could be a viable feed additive to include in their diet. By doing so, the need for antibiotics can be reduced, and the use of additives with a high carbon footprint can also be minimised. Based on the current research, we suggest implementing this feeding plan. However, additional studies should be conducted to validate our findings at the immunological level.

In terms of final body weight, providing a diet containing 1.30% Curcuma longa resulted in a body weight that was 11% higher (698 g/d) compared to the body weight achieved by Andrade-Yucailla *et al.*[37] when using a diet containing 3% Curcuma longa (620 g/d). Previous research on broiler and laying hens has shown that supplementing their diet with 0.9% and 0.5% of Curcuma longa resulted in increased body weight gain and improved feed conversion.[22,23] While Curcuma longa has been extensively utilised as a feed additive in animal production, there have been few studies conducted specifically on Cavia porcellus. Due to its diverse range of bioactive components, this perennial herb has garnered significant attention as a nutritional supplementing method among rural smallholders. Thus, our study found that a feed conversion rate of 2.30% was greater than the rates reported by Andrade-Yucailla *et al.*[37] and Djoumessi-Tobou *et al.*[31] when Cavia porcellus were given a supplement of 3% Curcuma longa. Nevertheless, our investigation found a 7% higher carcass yield compared to the findings published by Andrade-Yucailla *et al.*[37] (77% vs. 71%). Djoumessi-Tobou *et al.*[31] suggest that curcuminoid may enhance the production of emulsions in the gall bladder, hence improving nutrient digestion and perhaps leading to improved feed efficiency.

Conversely, hypercholesterolemia is a significant contributing factor to the development of atherosclerosis and consequent cardiovascular illnesses.[38] Various research have been conducted using animals as an experimental model to elucidate the connection between the risk of coronary heart disease and hypercholesterolemia.[38,39] Our findings demonstrate that feeding Cavia porcellus with Curcuma longa at a concentration of 1.30% leads to a drop in serum lipid levels. This effect is attributed to the increased activity of the enzyme cholesterol-7α-hydroxylase, as demonstrated by Hussein *et al.*[25]. Corroborating these findings, additional research conducted by Lebda *et al.*[21], and Hussein[40] in rabbits and broilers, respectively, has demonstrated notable reductions in cholesterol, tri-glycerides, and LDL cholesterol levels when the animals were administered Curcuma longa at doses ranging from 0.25% to 2% on a dry matter basis. Therefore, it is possible to speculate that the cholesterol-lowering effect of Curcuma longa may be due to its ability to stimulate the hepatic cholesterol-7α-hydroxylase enzyme, which plays a role in regulating cholesterol breakdown.[41] In addition, Murugan and Pari[42] noted a significant drop in levels of 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA), triglycerides, and free fatty acids when Curcuma longa was included as a feed additive. From these notable features, we inferred that Curcuma longa possesses exceptional antioxidant, metabolic, and immunological properties, making it a suitable choice for animal feeding as a substitute for antibiotics.[18] Our study found that including Curcuma longa at a dosage of no more than 1.30% can result in a 40% increase in profits compared to when Cavia porcellus are just fed fodder.

Conclusions

The addition of 1.30% Curcuma longa flour resulted in enhanced animal performances. Furthermore, there was a significant reduction in serum cholesterol levels, indicating that local food resources can be viewed as a viable and enduring substitute for use in animal production by small-scale farmers in Ecuadorian settings. Regardless, additional research should be conducted to substantiate our findings.

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Conflicts of Interest

The authors declare no conflict of interest.

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