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Chaya (*Cnidoscolus aconitifolius*) as an alternative for pig feeding

La chaya (*Cnidocolus aconitifolius*) como alternativa para la alimentación porcina

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Abstract

The objective of this research was to evaluate the influence of chaya (*Cnidoscolus aconitifoli*us) as an alternative for pig feeding during the growth stage. Prior to the development of the experiment, a characterization of the dehydrated plant material was carried out. A total of four treatments were used with three levels of inclusion of chaya flour (10 (T1), 20 (T2) and 30 (T3)%) plus a control treatment (T0). Pigs of 43 days of age with an average weight of 12 kg were used. In each treatment, the final weight, weight gain, feed consumption and feed conversion during the growth stage were evaluated. The results were analyzed using the InfoStat statistical program. The behavior of the pigs showed better results in the final weight in the treatments T0 and T3 with a weight of 57.51 and 57.62 $kg \cdot pig^{-1}$, respectively. In the same way, better results were obtained in weight gain with values of 44.62 and 44.80 $kg \cdot pig^{-1}$. Food consumption was similar in each treatment, registering a consumption of 83.69 kg. On the other hand, feed conversion was statistically better in treatments T0 and T3, with a total of 1.83 kg, respectively. It is concluded that chaya meal in concentrations of 30% can be considered a viable alternative for feeding growing pigs.

Keywords: unconventional foods; *Cnidoscolus aconitifolius*; nutrition; swine production; flours.

Resumen

El objetivo de esta investigación fue evaluar la influencia de la chaya (*Cnidoscolus aconitifolius*) como alternativa alimentaria para cerdos en la etapa de crecimiento. Antes de llevar a cabo el experimento, se realizó una caracterización del material vegetal deshidratado. Se emplearon cuatro tratamientos, que incluyeron tres niveles de harina de chaya (10 (T1), 20 (T2) y 30 (T3)%), además de un tratamiento testigo (T0). Se utilizaron cerdos de 43 días de edad con un peso promedio de 12 kg. En cada tratamiento se evaluaron el peso final, el incremento de peso, el consumo y la conversión de alimento durante la etapa de crecimiento. Los resultados fueron analizados utilizando el programa estadístico InfoStat. Los mejores resultados en el peso final se obtuvieron en los tratamientos T0 y T3, con valores de 57,51 y 57,62 $kg \cdot cerdo^{-1}$, respectivamente. De manera similar, se observaron mejores resultados en el incremento de peso, con valores de 44,62 y 44,80 $kg \cdot cerdo^{-1}$. El consumo de alimento fue similar en todos los tratamientos, con un registro de 83,69 kg. Por otro lado, la conversión alimenticia fue significativamente mejor en los tratamientos T0 y T3, con un valor de 1,83 kg, respectivamente. Se concluye que la harina de chaya en concentraciones del 30% puede considerarse una alternativa viable para la alimentación de los cerdos en crecimiento.

Palabras clave: alimentos no convencionales; *Cnidoscolus aconitifolius*; nutrición; producción porcina; harinas.

Introduction

Swine production is associated with the constant use of grains and protein sources in dietary formulations (Pan and An, 2020; Valverde et al., 2023). The use of balanced feed represents about 70%, other feeds 12.7%, whole or ground grains 8.6% and green fodder 5.3% (Gutiérrez et al., 2017); however, in Ecuador, these protein sources are underproduced for the most part. Therefore, they depend on imported raw materials to prepare a balanced diet, which generates an increase in production costs, increasing the problems for both manufacturing companies and small-scale pig farmers (Pazmiño and Ramírez, 2021).

Its production has been consolidated as an activity aimed at covering both economic emergencies and family demand for meat consumption and processed products (Barcaccia et al., 2020; Gomes, 2021), which are characterized by a high content of proteins, amino acids, vitamins, minerals, energy and micronutrients of high biological value in the human diet (Huang et al., 2021; Jerez et al., 2021).

Until 2000, the province of Manabí reached the highest national representation, with 31% of the total; however, in recent years a decrease in the development of this activity has been observed (Valverde et al., 2021). According to the latest report of the Survey of Surface Area and Continuous Agricultural Production (ESPAC, 2023), the swine population in Ecuador amounts to 943,249 live pigs, of which 95,521 are located in the province of Manabí, representing 10.12% of the total. The highest concentration is in the provinces of Santo Domingo de los Tsáchilas (22.70%) and Guayas (15.00%).

Over time, the swine industry has managed to improve production parameters by increasing lean meat production in order to increase producers' profitability through the payment of quality fees, reduce feed production cost and improve competitiveness (Barba et al., 2019; Peña et al., 2020). Generally, swine production in the rural sector has been developed as an activity that generates economic resources (Ron-Garrido et al., 2015); however, the development of this productive system has been affected by the cost of raw materials (corn, sorghum, soybean, among others) used in feed (Alvarado et al., 2018); however, the inclusion of by-products derived from agro-industrial activities or daily kitchen activities has been highlighted, among which wheat bran, cooked potato, cassava and ripe plantain stand out (El-Hage, 2022; Yafetto et al., 2023).

Preliminary studies have demonstrated the nutritional potential of chaya as an alternative in the feeding of different animal species such as poultry, pigs and cattle (Wongnhor and Khonyoung; 2022; Wongnhor et al., 2023). It stands out mainly for its protein contribution in the diet, being able to be substituted by a part of soybean or corn portions (active principles that limit the total substitution of this type of flour) (Totakul et al., 2021). Besides being considered as an alternative that contributes to the reduction of production costs and improves profitability (Herrera et al., 2019).

Chaya has been considered in animal nutrition for its high protein content (31.73%) and biomass production level (37.64 ± 10.78 ton-ha-1-yr-1 in fresh biomass and 6.46 ± 1.85 t-ha-1-yr-1 in dry biomass), reflecting, thus as a potential forage resource (Theissen, 2016). In addition, high levels of all amino acids except arginine and glutamine are highlighted (Ebel et al., 2019). It has been estimated that a 50 g serving of chaya can provide about three quarters of the daily requirement of valine, half of histidine, leucine and threonine; one third of isoleucine, lysine and methionine plus cystine, in addition to micronutrients such as niacin, riboflavin, potassium, calcium and magnesium (Panghal et al., 2021). The objective of this research was to evaluate the influence of chaya (Cnidoscolus aconitifolius) as an alternative for swine feed.

Materials and Methods

The experiment was carried out at the animal production unit of the Faculty of Animal Sciences, Technical University of Manabí, located at the Ánima site, San Antonio parish, province of Manabí, Ecuador. The geographical coordinates are 00°41.248' S and 80°07.457' W, with an altitude of 10 masl, and average temperatures of 34 °C (maximum) and 19.3 °C (minimum) (Google Earth, 2021).

Chaya bromatological characterization

Chaya (*C. aconitifolius*) was selected from different rural areas in the Chone municipality. Leaves and stems were collected randomly to obtain chaya flour after 90 days of the application of the equalization cut. The first step was to remove the stems and leaves and then leave them to rest for 15 days to eliminate as much water as possible in a natural way. Drying was carried out using an electric dehydrator for 3 hours at a temperature of 65 °C and subsequent grinding in an industrial hammer mill of artisanal manufacture. The sample was placed in hermetically sealed zip lock bags for subsequent analysis. The parameters protein (Test Method NTE INEN-ISO 20483), moisture (Test Method NTE INEN-ISO 712), ash (Test Method NTE INEN-ISO 2171), dry biomass (Test Method NTE INEN-ISO 712), fat (Test Method AOAC 2003. 06), crude fiber (Test Method AOAC 962.09), nitrogen free extract (Proximal Calculation), crude energy (Calculation), NDF (Test Method AOAC 973.18) and FDA (Test Method AOAC 2002:04).

Experimental design

The research was carried out using a completely randomized design (CRD), composed of three treatments plus the control (T0= 0% chaya flour, T1= 10% chaya flour, T2= 20% chaya flour, T4= 30% chaya flour). Each treatment consisted of five replicates, with one experimental unit per replicate. The pigs used were crossbred (Landrace x Petrain) of 43 days of age, which were in good health, dewormed and with the piglet vaccination protocol. Pigs of the same age, sex and genetic crossbreeding, with an average weight of 12 kg-pig-1 were selected. The pigs were placed in a house with 20 compartments (0.50 x 0.80 m). Each pen was equipped with its respective feeder and drinker in order to supply water *ad libitum.*

Diet formulations

The diets were formulated in accordance with the energy and protein requirements appropriate for the physiological state of pigs during the growth stage (Campabadal, 2009), and based on the nutritional requirements outlined by the NRC (National Research Council).

The diets used in this study were developed through the combination of raw materials and inputs listed in Table 1. The inclusion of the three levels of flour was determined based on the bromatological analysis of the Chaya flour samples (Table 2) and considering the acceptability observed in the cafeteria trial reported by Alcívar (2022).

Table 1. Formulation of pig diets with the inclusion of the three levels of Chaya meal.

Ingredients	Amount of ingredients per 100 kg (100%)			
	0	10	20	30
Corn	67,40	56,20	50,00	40,70
Soy	25,00	25,00	22,50	18,40
Chaya	-	**10,00**	**20,00**	**30,00**
Rice bran	4,00	4,00	1,20	4,00
Palm oil	0,70	1,50	3,00	3,10
nucleus of growing pigs	1,20	1,20	1,20	1,20
Carbonate	0,60	1,00	1,10	1,10
Dicalcium phosphate	0,70	0,70	0,80	1,10
Sodium chloride	0,40	0,40	0,20	0,4
Total	100,00	100,00	100,00	100,00

The balanced feed was provided during morning and afternoon sessions at fixed times (8:00 AM and 4:00 PM). For each treatment, the initial and final weight (kg·pig^{-1}), feed intake (kg·pig^{-1}), weight gain (kg·pig^{-1}), and feed conversion ratio (kg·kg^{-1}) were monitored.

Statistical analysis

The results obtained for the productive variables were analyzed using the statistical software InfoStat (version 24-03-2011, Grupo InfoStat, FCA, Argentina). An analysis of variance (ANOVA) was performed, applying Tukey's homogeneity tests with a 95% confidence interval. The results of the bromatological composition were analyzed using descriptive statistics (mean and standard deviation).

Results and Discussion

The results of the bromatological composition of Chaya leaves are presented in Table 2.

Tabla 2. Bromatological characterization of Chaya leaf.

Parameters	Unit	Average	Standard deviation
Protein (6,25)	%	23,57	5,48
Humidity	%	9,71	0,78
Dry matter	%	90,29	0,78
Fat	%	3,00	0,98
Ash	%	12,71	0,71
Raw fiber	%	14,37	5,43
Nitrogen-free extract	%	36,63	3,57
Brute energy	Mcal·kg^{-1} MS	3,73	0,16
FDN*	%	24,48	8,07
FDA*	%	18,71	10,48

*NFD (neutral fiber detergent) y AFD (acid fiber detergent).

As shown in Table 2, the Chaya leaves exhibit a significant protein content of 23.57%, suggesting that Chaya could partially replace maize in pig diets (Herrera et al., 2019). The protein contribution observed in the flour was influenced by the reduction in moisture content during dehydration, which resulted in a higher concentration of primary metabolites (Table 2). This finding aligns with Ramírez et al. (2021), who also reported an increase in protein concentration in Chaya leaf flour when moisture content was reduced.

The fat content recorded in Chaya flour was 3%, differing from the 7.85% lipid profile reported by Gregorio et al. (2022) for dehydrated "Chaya mansa" flour. The lipid profile of Chaya includes fatty acids such as linoleic acid, linolenic acid, oleic acid, stearic acid, palmitic acid, and myristic acid (Moura et al., 2019). These fatty acids play a crucial role in pig diets, serving as substrates for various enzymes and essential components of biological membranes (Guillermo et al., 2021). Additionally, they act as an energy source and exert significant effects on intestinal development, immune function, inflammatory response, and feed palatability (Garay et al., 2017).

The ash content, which includes minerals and crude fiber, revealed values of 12.71% and 14.37%, indicating high similarity. Studies by Scull et al. (2022) and Vázquez et al. (2023) on various shrub species have documented ash values ranging from 9.02% to 16.80%. These levels did not show any adverse effects on the productive indicators of animal species, including pigs.

The NDF (neutral detergent fiber) and ADF (acid detergent fiber) contents of Chaya flour revealed low levels of these compounds in the plant material. Alcívar (2022), in a study

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on the bromatological composition of dehydrated Chaya flour harvested 90 days after uniform cutting, reported low NDF and ADF content compared to other shrub species. These results were attributed to the low presence of compounds that form the lignocellulosic complex.

Productive Performance of Pigs Fed with Chaya Leaf Flour

As shown in Figure 1, the initial weight of the pigs did not exhibit statistical differences (p = 0.9425) among treatments, aligning with the findings of Montiel et al. (2023), who reported initial weights of 12.50 and 12.20 kg·pig^{-1}, respectively.

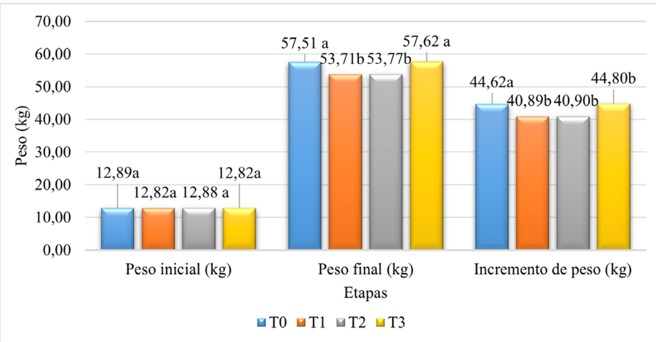

Figure 1. Behavior of Initial Weight, Final Weight, and Weight Gain of Pigs During the Growth Stage

Note: Values with different letters in the same row differ at p (α < 0.05); T0 = 0% Chaya flour, T1 = 10% Chaya flour, T2 = 20% Chaya flour, T4 = 30% Chaya flour.

The inclusion of 30% Chaya flour in the diet of pigs during the growth stage resulted in final weights similar to those of the control treatment, while being statistically different (p = 0.0001) from treatments T1 and T2. In this context, Rivero et al. (2020) reported similar results when using alternative feed options in pig diets, documenting a 30% substitution of balanced feed. This underscores the nutritional potential of such alternatives in pig diets during the growth stage.

Regarding weight gain, similar results were observed between the control treatment (T0) and the treatment with the maximum concentration of Chaya flour (30%). However, these treatments were statistically different (p = 0.0001) from T1 and T2, which showed lower weight gain. According to Vernaza et al. (2022), these variations in weight gain were associated with the availability of proteins in these feed types, a critical factor in providing the essential amino acids required for optimal productive development.

These findings highlight the significant protein contribution of Chaya in pig diets. Chaya proteins are composed of key amino acids such as alanine, arginine, glutamate, glutamine, histidine, isoleucine, lysine, methionine, phenylalanine, threonine, and valine (Tenesgen et al., 2022). Their presence in the feed contributed to improved productive indicators (Niemi et al., 2020), particularly considering the availability of these amino acids in the control treatment.

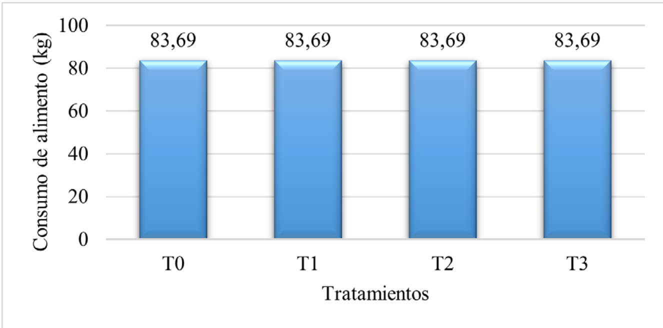

Figure 2. Feed Consumption Behavior per Pig During the Growth Stage.

Note: Values with different letters in the same row differ at p (α < 0.05); T0 = 0% Chaya flour, T1 = 10% Chaya flour, T2 = 20% Chaya flour, T4 = 30% Chaya flour.

On the other hand, it can be observed that the values for feed intake recorded for the treatments under study showed a proportional increase as the weeks progressed, reaching a total intake of 83.69 kg·pig^{-1} by the ninth week, respectively, in each treatment. This similarity in feed intake was attributed to the total consumption of the rations provided. According to Bergamaschi et al. (2020), these results were indicative of good health and productive performance of the pigs during the growth stage.

Preliminary studies using different types of unconventional flours during the growth stage of pigs have not shown significant effects on feed intake (Contino et al., 2017). A similar outcome was observed by González et al. (2021), who included diets with unconventional flours in comparison to commercial diets for pig feeding, finding no significant effects when using 30% unconventional feed, which aligns with the results obtained in this study.

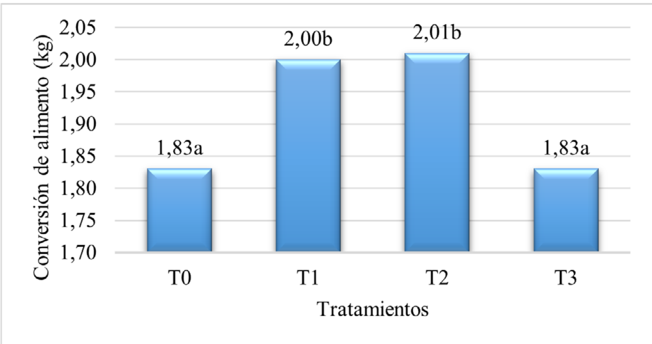

Figure 3. Average Feed Conversion Behavior of Pigs During the Growth Stage

Note: Values with different letters in the same row differ at p (α < 0.05); T0 = 0% Chaya flour, T1 = 10% Chaya flour, T2 = 20% Chaya flour, T4 = 30% Chaya flour.

Regarding the feed conversion values, it was observed that the inclusion of 30% Chaya flour significantly influenced ($p < 0.0001$) the feed conversion compared to the 10% and 20% concentrations. However, statistical similarity was found with the feed conversion of the control treatment.

Theissen (2016) indicated that the improvement in this indicator when using higher concentrations of Chaya flour showed a beneficial effect, which was associated with the quality and digestibility of the protein, similar to that reported for soybean flour. In this regard, Alcívar (2022), when characterizing the chemical composition and digestibility of Chaya flour, highlighted important results regarding the in vitro digestibility of the dry biomass and protein, which were 59.81% and 76.89%, respectively. The study concluded that this type of flour can be considered a viable alternative in pig diets, even in the presence of antinutritional substances described by Gregorio et al. (2022), which did not negatively impact the pigs' diet.

Conclusion

The inclusion of 30% Chaya flour (Cnidoscolus aconitifolius) in the diet of growing pigs proves to be a viable and efficient alternative, comparable to the control treatment in final weight, weight gain, and feed conversion. This approach optimizes production costs by partially replacing conventional inputs. Its high nutritional value, particularly its protein content and essential amino acid profile, confirms its potential as a sustainable local resource in pig feeding, without any significant adverse effects.

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Conflicto de intereses

Los autores declaran no tener conflictos de interés en la presente publicación en ninguna de sus fases.

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