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Phenotypic Variability of Native Guinea Pig (*Cavia porcellus*) Lines Associated with Productive and Reproductive Variables in the Traditional Production Systems of the Pastos Indigenous Reserve

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ABSTRACT

Genetic improvement seeks to meet human needs, resulting in a loss of genetic variability, affecting indigenous communities' biodiversity and food sovereignty. Therefore, this study aimed to determine the phenotypic variability of native guinea pig (*Cavia porcellus*) lines associated with productive and reproductive variables in the traditional production systems of the Pastos Indigenous Reserve in the Department of Nariño, southwestern Colombia. A total of 2007 guinea pigs older than 3 months were divided into 2 batches. 1934 individuals (batch 1) were randomly selected for phenotypic characterization, including hair length, leg size, body size, and behavior. Seventy-three individuals (batch 2) were used to evaluate productive and reproductive variables, and the lines with the highest similarity were clustered using the UPGMA method. In addition, ethnoveterinary information obtained through interviews within the production systems was described. As a result, nine traditionally known phenotypes were described including Shinhuzo, Pelochon, Zambo, Guarico, Chocolate, Peruvian, Coral, Piño, and Moro. The lines were clustered into 4 groups, highlighted by lines with high production and reproductive potential (group 1), lines with low progeny mortality (group 2), a line with low reproductive potential (group 3) a line that presented a unique coat and high productive potential as Group 1 (Group 4). As a result, local knowledge was shown to be crucial for the conservation of native guinea pig lines, as it includes traditional feeding techniques and disease treatment. The native lines Shinhuzo and Coral, with morphological differences between them, showed the potential to reach productive and reproductive parameters similar to the improved Peruvian line, according to the UPGMA dendrogram. However, a detailed analysis of the specific nutritional requirements of each guinea pig line is necessary to improve the traditional breeding of guinea pigs, enhancing the production of all native lines already adapted to the indigenous territory, maintaining the important genetic variability that, in the context of climate change, is relevant to promoting research on sustainable production strategies using resilient native species adapted to local conditions for the future exploration of differentiated markets.

Keywords: Animal conservation, Ethno-veterinary, Genetic variability, Traditional knowledge

INTRODUCTION

Domestication of animals and improving productive characteristics, such as weight gain and muscle strength have been developed to meet human needs (Alves et al., 2018; Lord et al., 2020). However, selection and inbreeding in populations of the same lineage bring significant problems, mainly the loss of genetic variability (Lacy, 1997). This is the case of native lines of guinea pigs (*Cavia porcellus*), which were affected by advances in intensive production and the adoption of improved varieties/breeds (Avilés et al., 2014; Díaz et al., 2016).

Native to the high Andean region of countries such as Colombia, Peru, and Ecuador, the domestic guinea pig belongs to the order Rodentia and is classified as *Cavia porcellus*, derived from its ancestor, the wild guinea pig (*Cavia tschudii*; Díaz et al., 2016; Lord et al., 2020). In Colombia, guinea pig production is associated with a traditional or indigenous management agroecosystem called "shagra" by indigenous communities (Rosero-Alpala et al., 2020) and is limited to the high Andean region near the border with Ecuador, where more than half a million guinea pigs are raised (Dalle-Zotte and Cullere, 2019). In this region, the guinea pig is economically and culturally significant, being the main animal that feeds on the bioproducts of the shagra system (Rosero-Alpala et al., 2020). Although guinea pigs are a fundamental basis for food sovereignty and a source of income for rural populations (Dalle-Zotte and Cullere, 2019; Benavides-Benavides et al., 2021), their low cost makes them an excellent alternative for sustainable production (Salvo et al., 2023). However, genetic improvement to obtain more efficient commercial populations for meat production is

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reducing the diversity of native lines, as they are considered low production lines due to their small size (Spotorno et al., 2004; Dalle-Zotte and Cullere, 2019; Lord et al., 2020).

For decades, guinea pigs have been produced in a traditional system that has been beneficial due to the herbivorous habits and reproductive parameters of guinea pigs (Rosales-Jaramillo et al., 2021). Commonly, the guinea pigs are often fed on kitchen waste when reared in rural smallholder houses (Dalle-Zotte and Cullere, 2019) and are reared from juveniles (0-150 days) to adults at 4-5 months, weighing 500-1500 g, at temperatures between 15-22°C (Ayagirwe et al., 2018; Grada et al., 2018). Although sexual maturity is reached at 2 months of age, the fecundity of females (up to 5 births per year) and the number of live offspring per birth (up to 6) are breed-dependent (Ayagirwe et al., 2018). The versatility of guinea pigs has allowed them to be distributed worldwide as companion, laboratory, or production animals.

The conservation of local animal sources of genetic variability has become a current area of research (Ayagirwe et al., 2017; Lord et al., 2020; Rosales-Jaramillo et al., 2021) because phenotypic features vary between populations, regions, and countries and depend on both the breed and the reproductive management system (Ayagirwe et al., 2019). For example, in Latin America, phenotypic characterization showed a significant difference in guinea pig morphology between Ecuador's two departments (Azuay and Cañar) (Rosales-Jaramillo et al., 2021). Similarly, in the Democratic Republic of Congo (DRC), the trichromic color pattern was the most dominant, while in Cameroon, it was more dichromic (Ayagirwe et al., 2017). Moreover, hair rosettes are known in South America but have not been reported in Africa (Ayagirwe et al., 2019). However, in Africa, data on guinea pig production is only available from 1968 onwards (Dorothy et al., 2014), as information on how and when the species was introduced into Africa is still unknown (Ayagirwe et al., 2017).

Molecular analyses suggest that the improved lines share a recent common ancestor with the European guinea pig, which is not the ancestor of the native Latin American lines (Spotorno et al., 2004). In addition, an independent domestication center of Cavia has been identified in Colombia. However, it is not related to modern Colombian guinea pigs (from markets), promotes the study of genetic diversity in specimens of Cavia species (Díaz et al., 2016), and the verification of a possible independent domestication process (Lord et al., 2020). Based on the above information, this study aimed to identify the different lines of guinea pigs present in the Gran Cumbal Indigenous Reserve, evaluating the morphological characteristics related to productive and reproductive development in the traditional production systems of the Gran Cumbal Indigenous Reserve, municipality of Cumbal, department of Nariño, Colombia. In addition, the use of traditional knowledge and ethnoveterinary medicine was described.

MATERIAL AND METHODS

Ethical approval

The experiments with Cavia porcellus from the indigenous reserve of Gran Cumbal (Cumbal–Nariño, Colombia) were conducted following the Animal Ethics Committee from the Universidad Católica de Oriente (Agreement #D-007/2024-05-31).

Location and experimental design

This research was carried out in the indigenous reserve of Gran Cumbal, 0º55' north latitude and 77º49' west longitude, in the department of Nariño, southwestern Colombia, in the large mountain massif called "Nudo de los Pastos", and only 3 districts were evaluated and chosen for high agricultural production (Cuaspud), Páramo with low agricultural and livestock production (Cuetial) and high livestock production (Boyera). The three sectors have different altitudes (Cuetial at 3400 m, Boyera at 3200 m, and Cuaspud at 3000 m), to evaluate possible differences in the productive and reproductive performance of guinea pigs between regions. Temperature and seasonal variation were not evaluated during data collection. All evaluations were conducted between the periods of high production between June-August (corresponding to the beginning of the summer period) and December-February (during holidays) between 2017 and 2020. Data collection was developed over three years to ensure that all guinea pig lines were characterized.

A total of 20 agroecological sheds were selected to determine the prevalence of native guinea pig lines. Only agroecological farms where traditional knowledge was practiced and/or animals were fed without supplements were included. Interviews, workshops, and surveys were conducted in the Boyera, Cuetial, and Cuaspud sheds. Activities such as traditional management, feeding, and health care (biosecurity) were considered influential factors in the production and reproduction parameters of the Indigenous community's production systems.

The procedures developed in this study are shown in the graphical summary. A total of 2007 guinea pigs of different ages (older than 4 months) were selected in the 20 agroecological sheds. Most agroecological systems (n = 16) used a wire cage housing system for guinea pig production. Another part (n = 4) had an unrestricted housing system inside the sheds, and the animals were reared freely on the ground. The animals were divided into batch 1 (n = 1934) for morphological evaluation and batch 2 (n = 73) to assess productive and reproductive parameters. Animals with breeding records were used for reproductive and productive evaluation, and animals without breeding records were used for morphological evaluation.

Evaluation of morphological characteristics *in situ*

An experimental group (n = 1934) was used for morphological characterization, according to the Ayagirwe et al. (2019) protocol. Briefly, 9 phenotypic variables were described, such as relative body size (small, medium, large), behavior (shy or docile), coat color pattern (monochromatic, dichromatic, trichromatic), coat length (< 2 cm short, 2-3 cm medium, > 3 cm large), relative leg size (small or large), eye color (red or black), ear orientation (erect, drooping), head profile (elongated or rounded), in addition to their frequency of presentation and use (medicinal, ritual, consumption, or sale) in traditional production systems was evaluated. The Peruvian line was used as a parameter to assess behavior, relative body size, relative leg size, and head shape since the line has a large body size (~34 cm), short coat (~1 cm), large legs (~2.5 cm), docile behavior and drooping ear (Chauca, 2023). According to the classification of Ayagirwe et al. (2019), the line showed an elongated head profile. The length of the legs (long or short) was described as "Yes = long legs", if the legs of the native line were equal to or longer than those of the control (~2.5 cm), "Not = short legs" if the legs of the native line were shorter than those of the control. This concept was applied to relative body size (small, medium, large) and coat length. The usual size of the Peruvian line (~34 cm) was categorized as large, medium if the animal had less than 5 cm to reach the reference value, and small if the animal had more than 5 cm to reach the reference value. Coat length was categorized as short (~1 cm), large (~4 cm), and medium (>1 cm and <4 cm). Numerical values were not presented as absolute values but only considered classification variables. The coat color, and eye color, were described without the use of the control characteristics. An example of this classification is shown in the supplementary Figure 1. All images were taken with a camera Nikon (Coolpix L330, Nikon, Japan).

Supplementary Figure 1. Phenotypic evaluation of male and female guinea pigs older than 4 months belonging to 9 lines found in traditional indigenous systems in the community of Pastos, Nariño, Colombia.
A: Determination of coat length (1), relative body size (2), ear with dropping orientation (3), and head with elongated profile (4). The values are presented as qualitative variables, using the standards of the Peruvian line. **B-D:** Manipulation of animals during data collection. Ear orientation (5), head with a rounded profile (6), and leg size (7). The standard values obtained in the Peruvian line were used such as control to some features. The Peruvian line has a large body size (~34 cm), short coat (~1 cm), large legs (~2.5 cm), docile behavior, and drooping ears. Statistical analysis was used to determine the length of the legs (long or short). Where Yes = long legs, if the legs of the native line were equal to or longer than those of the control (~2.5 cm), Not = short legs if the legs of the native line were shorter than those of the control. This concept was applied to relative body size (small, medium, large) and coat length. The usual size of the Peruvian line (~34 cm) was categorized as large, medium if the animal had less than 5 cm to reach the reference value, and small if the animal had more than 5 cm to reach the reference value. Coat length was categorized as short (~1 cm), large (~4 cm), and medium (>1 cm and <4 cm). Numerical values were not presented as absolute values but only considered classification variables. The coat color, and eye color, were described without the use of the control characteristics.

Assessment of productive and reproductive parameters *in situ*

Batch 2 (n = 73 animals) comprises the nine lines identified in the previous evaluation of morphological characteristics (Evaluation of morphological characteristics *in-situ* topic). The selected animals, aged 4-6 months, including males and females, were obtained only from agroecological sheds (n =16) that used a wire cage housing system for guinea pig production. The animals were identified and divided into couples (male and female) by native line in a single wire cage and placed in the same shed, in the Cuaspud district. The owner recorded and shared the reproductive records obtained over six months.

Productive variables

Body weight (BW) was determined by individual weighing (n = 73) using a mechanical hanging scale (Salter, #235-6S, New York, USA) in all the sheds. Mean weights were compared between lines, sheds, and districts.

Reproductive variables

A retrospective analysis was performed using breeding records (obtained in the results of the Productive variables topic) collected from adult females (n = 38). The variables assessed were mean weight (kg) obtained by individual weighing, number of live-born pups (NBA), stillbirths, number of pups per year (NPY), and mortality of pups to 3 months of age (M). The NPY value was obtained by multiplying the NBA by the number of annual reproductions (3.7 and 3.4 to improved and native lines, respectively) defined by Andean guinea pigs (Patiño-Burbano et al., 2019).

Dendrogram construction using the Unweighted Pair Group Method using Arithmetic averages (UPGMA)

The phenotypic, productive, and reproductive variables of the nine lines identified (Evaluation of morphological characteristics *in situ* and assessment of productive and reproductive parameters in situ topics) were used to construct a dendrogram using the unweighted pair group method with arithmetic mean (UPGMA) to cluster the lines with the highest similarity using Euclidean distances.

Ethno-veterinary application in traditional production systems

The assessment was carried out through oral communication and the "dialogue of knowledge" based on active participatory research with the guinea pig farmer of each shed (n = 20), following the recommendations of Rosero-Alpala et al. (2015). Information on each plant species was collected using the botanical and ethnobotanical format proposed by Rosero-Alpala et al. (2015). During the dialogue of knowledge, family members of each guinea pig farmer attended meetings to express their opinions.

Information on ethno-veterinary practices was verified by observing the practices *in situ*, noting how local communities use traditional methods and remedies, and through interviews providing first-hand accounts and insights into practices and their efficacy. In addition, the information was compared with written records of ethno-veterinary practices in this and other indigenous communities to provide context and support for current methods.

Assessment of biosafety and health in traditional guinea pig husbandry systems

The management and safety of the traditional guinea pig systems (sheds, n = 20) were self-assessed by the participating families using the evaluation form. An analysis of the main problems of this production was identified through technique visits (agronomist and veterinarian student) to each shed. The format was divided into 5 sections, with different topics evaluated on a scale of 1 to 10, where higher numbers indicate better performance or alignment with criteria according to Artica (2020). In the breeding environment section (20 points) was evaluated the luminosity (natural lighting) and window protection (mesh or curtains). In the materials and equipment (20 points) section was evaluated the constant cleaning of the shed and application of a disinfection program. In the infrastructure (40 points) section was evaluated the isolation method of guinea pigs (cages), the implementation of records: production, reproduction, and sales, the method of selection of guinea pigs (classified by size, line, and sex), and dead animal's management. In the animal feeding (20 points) section was evaluated the protection place for airing of forage and disinfection of forage before consumption. In the management of traditional knowledge (30 points) was evaluated the practices during animal feeding, animal care, and for disease treatment. The total score was 130 points. Each section applied 3 categories including values less than 75 of the reference score was considered productive imbalance, between 76 % to 85 % indicating a production that could be improved in some aspects, and greater than 86 % points indicating a good biosecurity plan with a balance of the productive system. a scale was 1 to 10, where higher numbers indicate better performance or alignment with criteria.

Statistical analysis

Qualitative variables are presented in frequency tables. Quantitative data were analyzed by ANOVA, followed by the Tukey test to evaluate the differences between lines. The data are represented as mean ± standard error. Analysis was performed using the software Rstudio version. 4.1 (Rstudio, Boston, U.S.A.), and a significant level was set at $p < 0.05$. The phenotypic and productive variables were used to construct a dendrogram (UPGMA) with the groups of most significant similarity using Euclidean distances.

RESULTS

Location and experimental design

The 20 sheds distributed across the three districts presented a variety of diets used in traditional production systems. Fifty-six percent (n = 9) of the systems had a diet based on forage consumption similar to that of cattle, such as ryegrass (*Lolium perenne*), alfalfa (*Medicago sativa*), oats (*Avena sativa*), clover (*Trifolium pratense L*). The 25 % (n = 4) feeding with other types of grasses such as Sonchus oleraceus or Taraxacum officinale, and 19 % (n = 3) were fed with crop residues, corn (*Zea mays*), broad bean (*Vicia faba*), cabbage (*Brassica oleracea*) and other vegetables.

Evaluation of morphological characteristics *in situ*

The study showed that in traditional management systems, there is a conservation of genetic resources, expressed in 9 phenotypes traditionally known as Shinhuzo, Pelochon-chilpudo, Zambo, Guarico, Chocolate, Peruvian (including Perú and Inti improved breeds), Coral, Piño and Moro. The frequency and specific description of each line are shown in Table 1. 35% of guinea pigs evaluated belonged to the Peruvian line (n = 676), and 65% were native lines (n = 1256). Within the native lines, Shinhuzo was easily found and represented 17% (n = 330) of all animals. Lines such as Chocolate and Piño were very little known, representing 1.7 % (n = 32) and 4 % (n = 78) respectively.

According to the producers, the relative size of the legs is considered a breed selection standard in the communities because it is related to productivity and reproductive efficiency. According to the results presented in this study, 7% of the indigenous community population uses the guinea pig as a medicinal source to treat some health problems, such as anemia and weakness after childbirth, preferring lines with black color, such as the Moro. Three percent use guinea pigs in rituals and festivals such as Inti Raymi (summer solstice) to ward off evil spirits. Most of the population (80%) use guinea pigs as a source of protein in their diet, and 10% of the population produces guinea pigs for sale. Most people who eat guinea pigs prefer roasted (90%), broth (6%), or stewed (4%).

Assessment of productive and reproductive parameters *in situ*

There was a significant difference ($p < 0.05$) between females' and male's weight, with a weighted mean of 0.95 ± 0.06 kg for males (n = 20) and 1.29 ± 0.10 kg for females (n = 53; Supplementary Table 1). In addition, there was no significant difference ($p > 0.05$) between lines between sheds ($p > 0.05$) and between districts ($p > 0.05$) evaluated (Supplementary Table 2). This study described feed consumption as the weight of feed offered but did not show the exact consumption value (Table 2). There was no significant difference in feed consumption among districts ($p > 0.05$, Supplementary Table 2), and the quality of feed used in the production systems by the district varied. Cuetial district is located in the highlands of the indigenous reserve, resulting in the lowest level of dairy cattle production, so there are lower quality pastures for guinea pigs, which can lead to lower average animal weight and higher feed consumption compared to the other districts. Boyera and Cuaspud are located in the more lowland region of the reserve, which favors agricultural production and directly affects the feed quality for guinea pig raising.

Reproductive variables

The results of the reproductive variables are shown in Table 3. No significant difference was found among the lines in the percentages of stillbirth ($p > 0.05$) and mortality up to 3 months ($p > 0.05$). The number of puppies born alive (BA) and the number of pups per year (NPY) showed a significant difference between the lines ($p < 0.05$).

Dendrogram construction using the Unweighted Pair Group Method using Arithmetic averages (UPGMA)

According to the UPGMA, the 9 lines were grouped into 4 groups: Group 1: Peruvian, Shinhuzo, and Coral;

Group 2: Moro, Guarico, Zambo, and Piño; Group 3: Pelochon Chilpudo; Group 4: Chocolate (Figure 1). The last two groups were described individually due to their high divergence in terms of their morphological and reproductive characteristics. Group 1 (Coral, Shihuzo, and Peruvian) showed high productive characteristics (weigh between 1.20 ± 0.14 to 1.23 ± 0.09) and reproductive potential. The reproductive variables such as high NBA (4.50 ± 0.34 to 4.70 ± 0.15), high NPY (15.75 ± 1.20 to 17.63 ± 0.57), and low stillbirth percentage (4.76 ± 4.19 to 6.15 ± 3.25), making these lines preferred for production and commercialization. Group 2 (Piño, Moro, Zambo, and Guarico) showed a high stillbirth percentage (15 ± 5.93 to 20 ± 5.13) with low mortality of pups (0 to 1.7 %). Group 3 (Pelochon-chilpudo) showed low reproductive potentials, such as low NBA (2.50 ± 0.50), high stillbirth (12.50 ± 7.26), and mortality (6.3 ± 0) percentage. The productive variables were similar to the other groups. Group 4 (Chocolate) was different in coat color (unique with gray and white colors) and coat color pattern, but it has a similar productive and reproductive potential.

Table 1. Phenotypic description of 9 lines of guinea pigs in the indigenous traditional systems of Cumbal, Nariño, Colombia

Lines of guinea pigs									
Character	**Moro**	**Zambo**	**Shinhuzo**	**Chocolate**	**Peruvian**	**Pelochon**	**Guarico**	**Coral**	**Piño**
Coat length	Short	Medium	Long	Short	Short	Long	Long	Short	Short
Size	Small	Small	Large	Large	Large	Large	Medium	Medium	Small
Behavior	Shy	Shy	Docile	Docile	Docile	Docile	Shy	Docile	Shy
Eye colour	Red	Black	Red	Red	Black	Black	Black	Black	Black
Ears orientation	Erect	Dropping	Erect	Dropping	Dropping	Dropping	Dropping	Dropping	Erect
Head profile	Rounded	Rounded	Rounded	Rounded	Elongated	Rounded	Elongated	Rounded	Elongated
Leg size	Medium	Small	Large	Medium	Large	Large	Medium	Small	Small
Coat color pattern	Dichromic	Trichromic	Trichromic	Dichromic	Monochromic	Trichromic	Trichromic	Dichromic	Dichromic
Coat colour	black and white	brown, beige, white	brown, beige, white, black	Gray, white	brown, beige, white, black	beige, white, black	brown, beige, white	brown, beige, white	beige, white
Use	S	C	S	C	S	C	C	C	C
n	183	225	330	32	676	210	20	180	78

The use of each line was determined to sell (S) or self-consumption (C). The data was obtained from 1934 individuals belonging to 20 agroecological sheds. n: Number.

Supplementary Table 1.

Group 2			
Sex	**N**	**Weight**	**p-value**
Male	20	0.95 ± 0.10[a]	P = 0.04
Female	53	1.29 ± 0.06[b]	P = 0.04
Total	73		

Data means average ± standard error. Identical superscript letters indicate non-significant differences as determined by the Tukey multiple-range test (*P > 0.05*).

Supplementary Table. 2.

Shed	**District**	**Total Animals**	**Feed (kg)/ day/ all animals**	**Feed (Kg)/ Day/Unit**	**Weight Mean**	**Weight Mean/ districts**
1	Cuetial	8	10	1.25	1.2	1.14 ± 0.09[a]
2		33	30	0.90	1.1	
3		30	50	1.66	1.52	
4		15	10	0.66	0.97	
5		32	20	0.62	0.83	
6		25	20	0.8	1.28	
7	Boyera	10	10	1	1.23	1.25 ± 0.09[a]
8		10	10	1	1.08	
9		70	50	0.71	1.25	
10		24	20	0.83	0.87	
11		25	30	1.2	1.38	
12		50	40	0.8	1.65	
13	Cuaspud	20	30	1.5	1.4	1.18 ± 0.12[a]
14		7	8	1.14	0.93	
15		30	20	0.66	1.17	
16		30	25	0.83	1.17	
Total		419	383			73

Data means average ± standard error. Identical superscript letters indicate non-significant differences as determined by the Tukey multiple-range test (*P > 0.05*).

Table 2. The production variable of 9 lines of 4 – 6 months guinea pigs in the indigenous traditional systems of the Pastos community, Nariño, Colombia

Line	N	Weight (kg)	Feed consumption (kg)
Moro	7	1.25 ± 0.18	1.00
Zambo	3	0.87 ± 0.26	1.04
Shinhuzo	13	1.20 ± 0.14	0.99
Chocolate	2	1.10 ± 0.32	0.96
Peruvian	27	1.23 ± 0.09	0.97
Pelochon	9	1.33 ± 0.17	0.99
Guarico	1	1.40	0.80
Coral	7	1.23 ± 0.18	0.80
Piño	4	0.85 ± 0.23	0.92
TOTAL	73		

Table 3. The reproduction variables of 9 lines of 3 – 6 months female guinea pigs in the indigenous traditional systems of the Pastos community, Nariño, Colombia

Line	NBA	Stillbirth (%)	NPY	M (%)
Moro	3.50 ± 0.29^{abcd}	20.0 ± 5.13	12.25 ± 1.01^{abcd}	1.7 ± 0
Zambo	3.00 ± 0.58^{bcd}	15.0 ± 5.93	10.50 ± 2.02^{bcd}	0.0 ± 0
Shinhuzo	4.67 ± 0.21^{ab}	4.76 ± 4.19	16.33 ± 0.74^{ab}	1.4 ± 0
Chocolate	3.50 ± 0.34^{abcd}	7.94 ± 4.19	12.25 ± 1.20^{abcd}	1.7 ± 0
Peruvian	4.70 ± 0.15^{a}	6.15 ± 3.25	17.63 ± 0.57^{a}	1.6 ± 0
Pelochon	2.50 ± 0.50^{d}	12.5 ± 7.26	8.75 ± 1.75^{d}	6.3 ± 0
Guarico	2.75 ± 0.48^{cd}	14.2 ± 0.0	9.63 ± 1.68^{cd}	0.8 ± 0
Coral	4.50 ± 0.34^{ab}	5.16 ± 4.19	15.75 ± 1.20^{ab}	0.8 ± 0
Piño	4.25 ± 0.48^{abc}	16.67 ± 5.13	14.88 ± 1.68^{abc}	0.0 ± 0

The number of pups born alive (NBA), number of pups per year (NPY), and mortality (M) of pups until they reach 3 months old. Data means average ± standard error. Identical superscript letters indicate non-significant differences determined by the Tukey multiple-range test (P > 0.05).

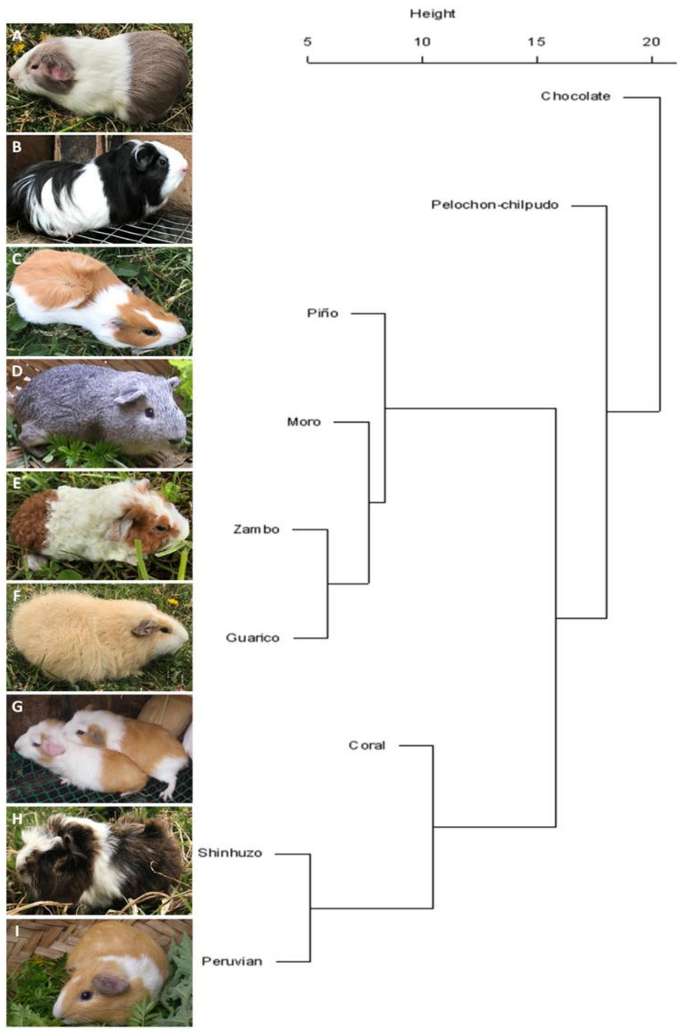

Figure 1. The dendrogram construction using UPGMA and reproduction and production variables of genetic resources of male and female guinea pigs, expressed in 9 phenotypes in the indigenous traditional systems of Pastos community, Nariño, Colombia. All phenotypes were described using the traditional name. A: the "chocolate". B: the "pelochon" with a long and straight coat. C: the "piño" with a hair swirl on the back, a specific characteristic of this line. D: the "Moro" with the dichromic coat (black and white). E: the “Zambo” with a coiled coat. F: the “guarico” with a long and curly coat. G: the “coral” with a hair swirl on the head, a specific characteristic of this line. H: the “shinhuzo" with a wavy coat. I: the Peruvian line. The lines were grouped into 4 groups, group 1: Peruvian, shihuzo, and coral; group 2: piño, moro, guarico, and zambo; group 3: pelochon-chilpudo; group 4: chocolate.

Ethnoveterinary application in traditional production systems

The information obtained through interviews, workshops, and surveys carried out in the sheds of Boyera, Cuetial, and Cuaspud showed a brief classification of the medicinal plants used in the traditional production of guinea pigs. The diseases found in the production systems were mainly related to fungi, internal parasites (traditionally known as “alicuya”), and external parasites (“piojera”) that affect young animals during the first months of life. Among the main diseases disclosed were "pepa" (Yersinia infection), respiratory and gastrointestinal diseases, and ectoparasites (Table 4). In traditional production systems, several plants are used to treat different diseases by oral or topical application and improve the environment (cages). The "gallinazo" and the eucalyptus were the first options for cleaning the cages. The plants were placed inside the cages for one or two days, and their efficacy was related to the pungent odor that characterized each. The herbal extracts offered for oral use were prepared by maceration of fresh green leaves of each of the plants until a slurry was obtained, which was mixed with water to facilitate oral administration; thus, this procedure was performed on animals in serious conditions that could not eat the leaves placed in the cages. When the extracts were for external use, fresh early leaves and stems were used, then placed in water and boiled for 30 minutes until a change in the color of the water was obtained (the ratio of leaves/water used was 10 leaves with stem/5L of water). The water had to be cooled and the animals were immersed in the warm water for a maximum of 2 minutes.

Table 4. The treatment of principal diseases that affect 9 lines of guinea pigs in the indigenous traditional systems of Cumbal, Nariño, Colombia

Disease	Organic system	Symptoms	Medicinal plant	Administration
Yersinia infection	Gastrointestinal Liver Linfatic system	Hepatic or splenic necrosis, abscess formation, mesenteric lymphadenopathy	Marco (*Ambrosia arborescens Mill*) Chilca negra (*Baccharis floribunda*) Gallinazo (*Tagetes zipaquirensis*) Verbena (*Verbena littoralis*) Guanto (*Brugmansia sanguínea)*	Fresh leaves* Fresh leaves* Fresh flowers and leaves* Leaves extract* Leaves-
Pneumonia	Respiratory Gastrointestinal	Nasal, ocular, or oral discharge, labored or rapid breathing, lethargy, emaciation, diarrhea, and bristly fur	*Eucalyptus globulus Labi* Marco (*Ambrosia arborescens Mill*). *Baccharis latifólia* Wormwood (*Artemisia absinthium L)*	Leaves extract* Leaves extract* Leaves extract* Leaves extract*
Parasites and fungus	External integuments	Loss of fur and peeling and itching in the affected area, hair loss, dermatitis, and crusts	Chilca negra (*Baccharis floribunda*) *Eucalyptus globulus Labi* Gallinazo (*Tagetes zipaquirensis*)	Leaves extract+ Leaves extract+ Leaves and flowers extract+

The information was collected through verbal communication in the "Dialogue of Knowledge" based on active participatory research with the community. Rout administration: * oral, + external, -housing disinfection

Assessment of biosecurity and health in traditional guinea pig farming systems

A self-assessment was conducted by a family member, and the strengths and weaknesses of their guinea pig production system were identified. Significant differences in biosecurity scores were observed between sheds and between districts ($p < 0.05$). In Boyera district, the average score was 108.67 ± 2.28, 90.25 ± 1.59, and 72.33 ± 3.4 for Cuaspud and Cuetial, respectively. The average score of all the farms was 89.4 points, indicating weaknesses in the traditional production system. In the average analysis of the sheds, it was found that their main weakness was the materials of equipment for cleaning (13.69) in contrast to animal feeding (18.06; Supplementary Table 3) where a higher score was obtained. Biosecurity and ethnoveterinary were important for producers to avoid using costly pharmaceutical treatments, opting for recovery, and traditional disease treatment techniques. However, the lack of cleaning facilities had a direct impact on the health of traditional productions since the prevalence of diseases was linked to sudden changes in temperature, with variations in humidity and air currents, typical of the transition from the dry season (summer) to the rainy season (winter). One of the main factors that favored the appearance of various respiratory and gastrointestinal symptoms was the dirty litter associated with abrupt changes in feeding, generating more food waste. In addition, the inefficient diagnosis of diseases in the early stages led to an increase in the proliferation of vectors including flies, and, therefore, an increase in the transmission of diseases between cages, triggering outbreaks of different diseases (Ethnoveterinary application in the traditional production systems section). Consequently, it was essential for the producers to establish an annual sanitary calendar to consider the season to prevent the outbreak of these diseases.

Supplementary Table 3.

Section	Reference score	Category*	Score of sheds
Breeding environment	20	Imbalance < 15, improve 16-17, balance > 17	13.69 ± 4.4
Materials and equipment	20	Imbalance < 15, improve 16-17, balance > 17	12.63 ± 2.61
Infrastructure	40	Imbalance < 30, improve 31-34, balance > 34	24.38 ± 6.55
Animal feeding	20	Imbalance < 15, improve 16-17, balance > 17	18.06 ± 6.60
Management of traditional knowledge	30	Imbalance < 22, improve 23-25, balance > 25	21.69 ± 11.83
Total	130		89.44 ± 19.56

* For each section was applied 3 categories: values less than 75% of reference score (imbalance) between 76% to 85% (production that can improve in some aspects), and greater than 86% (good biosecurity plan with a balance of the productive system).

DISCUSSION

In the context of climate change, it is important to promote research into sustainable production strategies using resilient native species adapted to local conditions. The sheds were selected in three different production areas, which are sectors with high agricultural production (Cuaspud), Páramo (Cuetial), and high livestock production (Boyera). Furthermore, the vegetation management in these systems considers the different climatic factors present in the different altitudinal bands of the indigenous reserve (Rosero-Alpala et al., 2015). The production and biosecurity of guinea pigs were lower in the intervened areas of the Páramo due to the scarcity of feed, in contrast to the agricultural and livestock production districts. This situation corresponds to the environmental and vegetation peculiarities of the Andean ecosystem, where the availability of forage varies according to the altitudinal gradient. According to studies by Rosero-Alpala et al. (2020), in páramo areas, guinea pigs feed on the foliage of native shrubs and by-products of Andean tuber crops. Among the species with forage use are: Black elderberry (*Sambucus nigra*), sauco (*Sambucus peruviana*), chilca (*Baccharis latifolia*), and carrizo (*Genus chusquea*), these species have characteristics of high adaptability, biomass production, and excellent nutritional quality (Cardona et al., 2020).

In the traditional production systems, the native lines of guinea pigs predominate, with a prevalence of 65%, compared to the improved lines, such as the Peruvian, which represent 35%. Among the native lines, the Shinhuzo has been highlighted for its large size and resistance to disease. However, in intensive production, 85.5% is based on improved lines, while only 14.5% corresponds to native lines (Chávez-Tapia and Avilés-Esquivel, 2022). In addition, in the municipalities of Nariño, there are approximately 20000 small guinea pig farms with artisanal production, which have the production to support the family economy (Barco-Jiménez et al., 2021). According to Avilés et al. (2014), this panorama shows a typology of production and transition in guinea pig farming due to the economic factor of subsistence and family income. However, the development of the commercial production system has allowed the introduction of improved lines in the Andean region, reducing the production of native guinea pig lines. The results of the present study showed that 93% of the activities in guinea pig farming were carried out by women, revealing a notable gender predominance in the breeding, production, and conservation of indigenous lines of guinea pigs. Similarly, in intensive production, production management is also developed by women, with 76.6% of activities carried out by women (Chávez-Tapia and Avilés-Esquivel, 2022). Moreover, for several decades, small livestock species such as pigs, guinea pigs, and chickens have been reared by women in 57.1% of cases, while men alone carry out this activity in 4.8% of cases, reflecting the integration of women in the productive activities of rural families (Giraldo, 2008). The rural women in Nariño implement resilient actions in front of food and nutrition security through agroecological production practices. The women's gardens, which include vegetables, legumes, aromatic herbs, and medicinal plants, have integrated a livestock system with the raising of guinea pigs and chickens, reducing dependence on external inputs such as fertilizer for crops and feed for animals and facilitating the development of short marketing chains through agroecological markets (Bacca-Acosta et al., 2024).

This study showed the low reproductive potential of the native guinea pig lines compared to the improved lines. Only the Shinhuzo and Coral lines exhibited high reproductive potential. The limited performance of the native lines is attributed to their innate characteristics of resistance to disease, hardiness, and adaptation to the environment (Quispe et al., 2021). Similar studies developed by Patiño-Burbano et al. (2019), who evaluated the behavior of productive and reproductive variables of improved lines and several native lines in Nariño and Putumayo, showed that the improved lines had a lower age at first mating (months) (Peruvian line (5.1) and Andean (4.5) than the native lines (5.3). The number of births/female/year in the Peruvian and Andean lines was 3.7 and 3.4 in the native lines. The average weights at birth, weaning, and slaughter were higher in the improved lines than in the native lines, and the age at weaning was lower in the improved lines. Similarly, the study of David-Martínez et al. (2016) showed that the best averages of weights, litter sizes, fertility, birth rates, and calving intervals were obtained by the Peruvian breed in the context of genetic crossbreeding between purebred populations of native lines from Nariño and Peruvian origin. During the evaluation of reproductive performance, the animals were placed in the same shed, in the Cuaspud district, to avoid biases in the results related to the variety of feed quality between districts. These results indicated that low performance was line-dependent. Therefore, the specific factors (hormonal, genetic, or environmental) involved in the lower reproductive performance of the native lines should be studied.

Another aspect related to low reproductive potential in indigenous lines may be determined by diet (Cardonas et al. 2020; Vargas, 2022). According to Cardona et al. (2020), nutritional factors also play a fundamental role in the growth and reproduction of guinea pigs; low and high levels of protein and carbohydrates reduce the body's fat and weight loss, in addition to low fertility and reproductive performance. Although in the present study, the relative feed consumption did not show a difference between consumption and weight between native and Peruvian lines, the biometric growth of guinea pigs depends largely on the diet, which should be mediated by a diet rich in vitamins, proteins, fats, minerals, and carbohydrates, so it is important to consider implementing a feeding system that generates a balanced consumption between forages and other food supplements. Since feed represents 70% of the cost of raising guinea pigs, it is necessary to determine the chemical composition and energy intake of the feed according to the requirements of each guinea pig line (NRC, 1995; Castro-Bedriñana and Chirinos-Peinado, 2021). Some studies have shown differences in the productivity of guinea pig lines under the same diet (Vargas, 2022). Reynaga-Roja et al. (2018) found differences in the productive behavior of guinea pigs of improved breeds, such as Peruvian, Inti, and Andean, where in a diet based on formulated feed plus chala corn, the Peruvian breed obtained higher slaughter weights, while for the Inti line it was less efficient.

On the other hand, the traditional knowledge of diseases, breeding techniques, and preservation of the native guinea pig is characterized by its focus on sustainable production based on native agro-food systems. According to Lastra-Bravo (2020), indigenous food systems emerge from an ancestral response with a significant component of resilience and environmental management. Therefore, a key element in the fight against hunger and poverty and promoters of sustainable agricultural practices that guarantee food sovereignty for indigenous communities. In traditional guinea pig production, animal health diagnosis is based on characteristic macroscopic findings. According to the findings of the present study in the indigenous community of Pastos, the disease with the highest prevalence, identified by reported symptoms, was *Yersinia* infection, commonly known as "Pepa". The infection affects the gastrointestinal tract and causes sepsis with secondary involvement of the liver, lymph nodes, and spleen (Mansfield and Fox, 2018). Although the prevalence of this disease may be related to the characteristics of guinea pig production systems (Benavides-Benavides et al., 2021), the type of housing system, such as unrestricted housing system or wire cages, does not appear to significantly affect growth performance, feed consumption, carcass characteristics, mortality, or fattening of guinea pigs (Mínguez Balaguer et al., 2019). Thus, in the context of production systems for food and nutrition, in the indigenous community of Pastos, aspects of local use of medicinal plants are considered for the treatment of internal and external diseases in domestic species such as guinea pigs, which are used in human food. According to Muyuy-Ojeda (2019), the communities of Inga and Kamentsa also use plant species for the care of guinea pigs. Among them, lemon balm (*Melissa officinalis*), vervain (*Verbena officinalis*), and garlic (*Allium sativum*) are used to treat gastrointestinal and respiratory diseases; marigold (*Calendula officinalis*) and chamomile (*Chamaemelum nobile*) are used to combat skin fungus; pumpkin (*Cucurbita ficifolia*) and paico (*Chenopodium ambrosioides*) for deworming; and botoncillo (*Sphylantes sp*) to control external parasites such as lice.

CONCLUSION

The native lines of guinea pigs showed the potential to achieve productive and reproductive parameters similar to those of the improved Peruvian line. In addition, the Indigenous families involved in this activity could benefit by strengthening their capacity to manage guinea pig farming sustainably and efficiently. However, further studies are needed to determine the values of specific consumption rates to obtain a dietary formulation for each indigenous line and to achieve productive efficiency. In addition, local knowledge was crucial for the effective conservation of native guinea pig lines, as it includes traditional feeding techniques, treatment of diseases with medicinal plants, and the use of sustainable practices such as composted substrates and biofertilizers in the "Shagra" farming system. It generates perspectives for the conservation and rescue of this species and the territories where it is found and within the current social challenges. Therefore, it is appropriate to promote research on mitigation strategies with sustainable production alternatives within agricultural systems that use resilient native species adapted to local conditions and the exploration of differentiated markets.

DECLARATIONS

Availability of data and materials

All data generated or analyzed during the current study are included in this article.

Authors' contributions

Jenyffer Rosero conceptualized, investigated, performed the data analysis, and wrote the original draft. Maria Gladis Rosero Alpala performed, validated, and visualized the methodology. Deisy Rosero performed the data curation and methodology. Alicia Rosero performed the methodology. William Armando Tapie: conceptualized, supervised, validated, reviewed, and edited the draft. All authors have read and approved the final version of the manuscript before publishing it in the present journal.

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Competing interests

The authors declare that they have no competing interests.

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Ethical considerations

The authors considered ethical concerns and Cabildo Indigena del Gran Cumbal consent to conducting and publication of this research. This article has not been published elsewhere and is copyrighted by the authors. The authors have checked the article for plagiarism index and confirmed that the article is based on original scientific work.

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