Nutritional management of *Cavia porcellus* L. in the Andes of Colombia

Manejo nutricional de *Cavia porcellus* L. en los Andes de Colombia

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Abstract

The *Cavia porcellus* L. systems implemented by small producers in Colombia have been slow in applying the processes of development and incorporation of feeding practices and technology in nutritional support. The objective of this study was to determine the feeding practices and technology in nutritional support implemented and projected in the *C. porcellus* L. systems by the producers. Four components were evaluated in 404 *C. porcellus* L. units and 29 focus groups: demography, identification of the production unit, implemented feeding practices, technology in nutrition and feeding, and the *C. porcellus* L. producers' perspectives. A Pearson Chi-squared test, a Tukey's T-test, and a Multiple Linear Regression were used to evaluate the differences between regions using SPSS software version 20. The average area of *C. porcellus* L. -producing units corresponded to 0.35 ha (Nariño) and 0.17 ha (Putumayo). The predominant food base was forage (67%) produced on the farm (83%). There were significant differences between regions, with a $p < 0.05$ in food base, forage cultivation area, forage conservation feeding practices, type of fertilization, and the group of animals supplemented. The use of technology such as feed based on kitchen waste and supplements was used by producers in the Putumayo region ($p > 0.05$) most frequently. Our data show that *C. porcellus* L. systems in the study area not only have a high potential in the diversity of the forage supplements that makes up the diets but also in the development and implementation of feeding practices and technology in nutrition and animal feeding.

Keywords: *Cavia porcellus* L., feeding practices, availability of local forage, supplement use

Resumen

Los sistemas de *Cavia porcellus* L. desarrollados por pequeños productores en Colombia enfrentan procesos de desarrollo e incorporación de prácticas en nutrición y alimentación con baja aplicación. El objetivo de este estudio fue determinar las prácticas en nutrición y alimentación implementadas y proyectadas en los sistemas de *C. porcellus* por los productores. Cuatro componentes: demografía, identificación de la unidad productora, prácticas en nutrición y alimentación implementadas y proyectadas por los productores de cuyes fueron evaluadas en 404 unidades productoras y 29 grupos focales. Un test de Chi cuadrado de Pearson, una prueba Tukey y una Regresión Lineal Múltiple fueron usados para evaluar las diferencias entre regiones a través del Software SPSS versión 20. El promedio de área de las unidades productoras correspondió a 0,35 ha en Nariño y 0,17 ha en Putumayo. La base alimenticia predominante fue forraje (67 %) producido en la finca (83 %). Existieron diferencias significativas en la base alimenticia, área de cultivo y prácticas de conservación del forraje, tipo de fertilización y grupo de animales a los que suplementa entre las regiones con un p <0.05. La alimentación con base en residuos de cocina y suministro de sal mineralizada se encontró con mayor frecuencia en la región de Putumayo (p >0.05). Los datos muestran que los sistemas de producción de cuy en el área de estudio tienen un alto potencial en la diversidad de la oferta forrajera que compone las dietas, y en el desarrollo e implementación de prácticas y tecnologías en nutrición y alimentación.

Palabras clave: Cuy, prácticas de alimentación, disponibilidad de forrajes locales, uso de suplementos

Section: Original article

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Introduction

Andean mountains are cultural landscapes, long dominated by land uses associated with subsistence agriculture where *Cavia porcellus* L. is considered a cultural and natural resource to improve the quality of life and economic sustainability in the Andean communities (Maldonado, 2019). *C. porcellus* breeding had had relation to cultural aspects from the gastronomic to the spiritual, which date back to pre-Inca times (Arcos Morales *et al.,* 2017), and most of the production is consumed or exported where the people of the Andes live (Mínguez Balaguer *et al.,* 2019).

It production provides a regular supply of high-quality animal protein which contributes to food security

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and also provides a small but consistent income to producers (Ngoula *et al.,* 2017). Currently, food security initiatives for small producers consist of prioritizing interventions to support local research and innovation (Rybak *et al.,* 2018).

Andean countries are directly related to family, peasant, and indigenous economies, where women have a significant leadership role transmitted through the generations (Patiño Burbano *et al.,* 2019). *C. porcellus* feeds mainly forage and does not compete directly with humans for food resources such as corn and wheat (Ramirez-Borda *et al.,* 2019). The natural diet includes a combination of wild fruits, leaves, and forages, specifically those with a short growing season located in its habitat. In confined diets feeds are grass hay for the adult stage and mixtures of hay/alpha for the growth stages and lactating females, *C. porcellus* being one of the few herbivores that naturally transport *Lactobacillus* in the gastrointestinal tract (Grant, 2014).

C. porcellus does not adapt quickly to changes in diet and water (Shomer *et al.,* 2015), and the main nutritional requirements consist of 10 to 16% of crude protein (CP) in the adults, and 18–20% in the growth stage, 15% of fiber, 0.80% of calcium, 0.40% of phosphorus, 6.6 IU/kg of Vitamin A, and 200 mg/kg of vitamin C (Cardona-Iglesias *et al.,* 2020; León *et al.,* 2016). Animal feeding is considered to be one of the factors that directly affect the production, reproduction, and quality of the carcass and meat in *C. porcellus*, in fact they grow well with the food waste from kitchens, although it is possible to increase meat production using concentrates and dietary supplements (Sánchez-Macías *et al.,* 2018).

Sociocultural and economic factors determined the diversity of food resources in the nutritional management in the study area, thus, diets depend on the traditions in the habit of using forage species, the ethnic origin of the producers, the access and distance to places where some species were ancestrally harvested, and the line of transmission of knowledge in the management of production, which is mainly matriarchal (Perilla, 2014). Additional factors could be too traditional knowledge and feeding practices, formal and non-formal education, extension systems, and relationships with the community (Gobernación de Nariño, 2019).

In the study area, some nutrition and feeding practices have been described, however, some productive and reproductive parameters still have low efficiency. According to Caycedo *et al.,*(2011), the principal food source for *C. porcellus* corresponds to cultivable pastures, forage trees, and local forages. We describe the current state and scope of nutrition and feeding practices and technology in *C. porcellus* husbandry, relating to the key drivers that influence the incorporation of suitable technology. The objective was to identify the feeding practices and nutrition and feeding technology implemented and projected in the sociocultural and natural systems of *C. porcellus* in the Andes.

Material and methods

Study area

The farmers for this study were selected at the villages Pasto (Nariño) and Colón, Santiago, and San Francisco

Figura 1. Location of the study area.

(Putumayo) in the South of Colombia (Figure 1). The study area corresponds to Humid Montane and Low Montane Forest, with altitudes between 2000 and 3000 asl, mean annual rainfall from 500 to 2000 mm, and temperatures between 6 and 18°C (Holdridge, 1967). Peasants (57%) and indigenous (43%) populations were surveyed.

Data collection and data analysis

The sample size was calculated from the producer databases (n=1058 at 99% of confidence) available in the study area. The data collection conducted was a part of the project to expand regional research and innovation in small farmers of *C. porcellus*. We conducted face-to-face primary structured surveys during 29 focus group with *C. porcellus* producers from May to July of 2017 in 404 systems (38% of the total population).

Four dimensions and 38 variables are analyzed: demographics (n=6), production unit (n=2), feeding practices, and technology implemented by producers in nutrition and feeding (n=12), as well as the viability of feeding practices and prospects of that producer (n=19). Responses were hand-noted and the survey digitized in Microsoft Excel.

SPSS Software version 20 (SPSS Inc., NY, USA) was used to analyze collected data. The categorical variables were described by using frequencies and percentages (Moreno Grajales, 2017). The Pearson Chi-squared test was applied to assess differences in (Rybak *et al.,* 2018) nutritional management for categorical variables and a Tukey's T-test for quantitative variables between regions. Significance was measured when $p < 0.05$. Multiple Linear Regression was carried-out to identify factors that grant implementing nutrient management practices in the systems.

Table 1. Animal feeding practices in the study area

Feeding practices	Nariño %	Putumayo %	P <0.05
Food Basis			0.00001*
Forage	67	36	
Concentrate	1	1	
Forage and concentrate	30	59	
Agricultural by-products and kitchen waste	2	4	
Origin of forage			0.05106
Buys it	3	10	
Produces it on the farm	83	74	
Buys it and produces it on the farm	9	12	
Harvests it through ancestral feeding practices	5	4	
Area of forage			0.00000*
Small	59	78	
Large	34	7	
No area to be allocated	7	15	
Forage conservation feeding practices			0.01532*
Yes	5	11	
No	89	79	
Don't know them	6	10	
Fertilization			0.00409*
Yes	86	75	
No	14	25	
Fertilization			0.00001*
Organic	62	70	
Chemical	4	2	
Organic and chemical (mixed)	20	3	
No	14	25	
Nutritional supplements			0.96856
Yes	34	34	
No	66	66	

Group you supplement	Yes	No	Yes	No	
Females and males before mating	13	87	20	80	0.04860*
Females before mating	2	98	2	98	0.72268
Males before mating	2	98	3	97	0.50147
Gestation	14	86	22	78	0.04203*
Fattening	20	80	25	75	0.19282
Weaning	29	71	24	76	0.31537

* Significant Chi-squared test at p<0.05

The dependent variable was the level of education of the farmer. Explanatory variables corresponded to gender (demographics), the origin of forage, use of nutritional supplements, group of animals you supplement – pregnant females (production unit), food based on kitchen waste, feeding based on fresh pasture mixtures (current technology), and familiarization with fodder selection according to nutritional content (projected technology).

Results

Demographic characteristics

According to the municipality, the distribution of producers surveyed corresponded to Pasto (50%), Colón (13.4%), Sibundoy (27%), San Francisco (3.7%), and Santiago (5,4%). The predominant gender was women (Nariño 80% and Putumayo 87%), with no significant differences within the regions (p<0.05 =0.0725). A low proportion of illiteracy was reported (90%) among producers, with no statistically significant interregional differences (p < 0.05 = 0.2099).

Most producers in both regions have completed their primary basic education (Nariño = 63% and Putumayo = 57%). The high school rate was 12% (Nariño) and 15% (Putumayo). The proportion of farmers who had high school was 19% (Nariño) and 14% (Putumayo). A low proportion of producers in both regions with technical (Nariño = 5% and Putumayo= 10%) and bachelor degree levels of education was reported (Nariño = 1% and Putumayo =3%). In the Putumayo region, was found no formal education (1%). No statistically significant differences for the literacy level variable were found (p < 0.05 = 0.2099) across regions.

The survey revealed the breeding of *C. porcellus* is carried out by women who have dedicated more years to the process of implementation and care than men in the two departments. The average age of men (51.35 years) caring for *C. porcellus* in Nariño was higher than women (47 years). The Putumayo area reported an average age in women (47 years) higher than men (43 years). No significant differences were found at p < 0.05 = 0.1352 by Tukey test across regions for the average age variable. Women in charge of the systems are older than men.

Production unit

The average area of productive units corresponded to 0.35 ha (Nariño) and 0.17 ha (Putumayo), with a higher area dedicated in Nariño. A predominance of small-holdings and micro-holdings had reported, where 99% of the systems surveyed had production units ranging in

Table 2. Forage availability reported in *C. porcellus* systems

Region/Type	Common name	Scientific name	%
Nariño			
Gramineae	Saboya	*Holcus Lanatus*	70
	Kikuyo	*Cenchrus clandestinus*	66
	Brasilero	*Phalaris arundinacea*	58
	Rye Grass Tetralite genotype	*Lolium hybridum*	43
	Rye Grass Aubade genotype	*Lolium hybridum*	17
	Blue orchoro	*Dactylis glomerata*	7
	Oat	*Avena sativa*	4
	Maralfalfa	*Pennisetum sp.*	2
Legumes	White clover	*Trifolium repens*	53
	Alfalfa	*Medicago sativa*	12
Trees	White Chilca	*Baccharis latifolia*	5
	Elderberries	*Sambucus nigra*	1
	Black Acacia	*Acacia decurrens*	1
	Alder tree	*Alnus glutinosa*	1
	Gold Button	*Thitonia diversifolia*	5
Local forage species	Wounded heart	*Eupatorium niveum*	8
	Knucke	*Oplismenus barmannii*	4
	Achicoria	*Cichorium intybus*	4
Putumayo			
Gramineae	Imperial	*Axonopus scoparius*	59
	Saboya	*Holcus Lanatus*	47
	Rye Grass Tetralite genotype	*Lolium hybridum*	38
	Kikuyu	*Cenchrus clandestinus*	30
	Cutting edge grass	*Hyparrhenia rufa*	18
	Maralfalfa	*Pennisetum sp.*	16
	Honey grass	*Paspalum dilatatum Pior*	7
	Purple Elephant	*Pennisetum purpureum*	6
	Blue orchoro	*Dactylis glomerata*	3
	Oat	*Avena sativa*	1
	Rye Grass Aubade genotype	*Lolium hybridum*	1
Legumes	White clover	*Trifolium repens*	6
	Alfalfa	*Medicago sativa*	2
Trees	Gold Button	*Tithonia diversifolia*	31
	White Chilca	*Baccharis latifolia*	1
	Mulberry	*Morus alba*	1
Local forage species	Knucke	*Oplismenus barmanni*	8
	Botoncillo	*Sphylantes sp.*	5
	Ramie	*Boehmeria nívea*	6
	Pacunga	*Bidens sp.*	4
	Wounded heart	*Poligonum nepalense*	4
	Reed rush	*Schoenoplectus californicus*	2
	Milky	*Euphorbia heterophylla*	2

size from 0.0001 to 0.25 ha (Nariño) and 0.0001 to 0.85 ha (Putumayo), respectively. A small part of the assessed population (less than 1%) owned extensions ranging from 1 ha (Putumayo) to 2 ha (Nariño).

The farmers traditionally developed their systems on their land (92% Nariño and 88% Putumayo). Other forms of land tenure found in the study corresponded to leased land with 5% (Putumayo) and 9% (Nariño). In some cases, producers´ family lands (3% Nariño and 2% Putumayo) or community systems indigenous reservations (1% Putumayo) were reported, with no statistically significant differences (p < 0.05 = 0.5041) across regions.

Animal feeding and technology practices

The most important source of food was foraging (Nariño), and mixtures made of forage and concentrate (Putumayo), with significant differences between regions (Table 1). The practice of allocating areas for forage cultivation was predominant in the research area, with smaller areas for forage production used to feed, occurring with a significantly higher frequency (78%) in Putumayo (p < 0.05 = 0.01532).

Despite forage conservation feeding practices being known in the study area, a low proportion of producers have implemented them on their farm. According to the results, the Putumayo producers (11%) had implemented its technology at a higher level than the Nariño producers (5%). The use of dietary supplements in the systems was not usual among producers (34% in each region - Table 1). Significant differences were observed between regions in supplementation to males and females before mating (p < 0,05 = 0.0486), and female supplementation in the gestation period (p < 0,05 = 0.0420) where the highest frequency occurred in Putumayo (22%).

Forage fertilization practices were carried out in most of the properties of the study area, having a greater use in Nariño (86%), along with the application of organic fertilization (62% Nariño and 70% Putumayo - Table 1),

Table 3. Nutrition and food technology implemented and with feasibility of implementation

	Nariño %		Putumayo %		P <0.05
Current technology	Yes	No	Yes	No	
Kitchen waste	24	76	81	19	0.00001*
Fresh pasture mixtures	84	16	84	16	0.95885
Feeding frequency / Twice/day	25	75	14	86	0.00376*
Feeding frequency / Three times/day	20	80	20	80	0.88012
Forage bank	3	97	4	96	0.75031
Multi-nutritional blocks	3	97	2	98	0.54268
Supply of mineralized salt	2	98	11	89	0.00369
Dehydration of forages	6	94	3	97	0.16034
Projected technology					
Multi-nutritional blocks	38	62	33	67	0.32117
Production of concentrates	63	37	60	40	0.64266
Hydroponic crops	10	90	22	78	0.00136*
Forage preservation process	14	86	19	81	0.1558
Familiarization with fodder selection according to nutritional content	21	79	20	80	0.88315
Mineral and vitamin supplement	3	97	2	98	0.5814
Diets management by productive stage	11	89	11	89	0.94312
Grassland management	2	98	2	98	0.9747
Water Supply and Facilities Management	1	99	1	99	0.37772
Sprout management and grain processing	2	98	4	96	0.30539

[*] Significant Chi-squared test at p<0.05

with no significant differences.

60 forage species constituted the source of food resources used by *C. porcellus* producers in the study area. The predominant species group in the composition of diets corresponded to Gramineae and the use of local forage and tree resources. Comparatively, a greater diversity of local grasses and forage species were found, respectively, in Putumayo compared to Nariño (Table 2). The diet composition of *C. porcellus* in the regions is shown in Table 2.

Prospects of animal feeding practices and technology

Seven animal feeding practices and technologies were used in the regions, technologies such as kitchen waste-based feeding, feed based on mixtures of fresh forage, frequency of feeding, forage banks, multi-nutritional blocks, mineralized salt, and dehydrated forage were implemented (Table 3). There were significant differences in the use of technology included feed based on kitchen waste and mineralized salt supply, used more frequently in Putumayo and the variable feed frequency twice/day used by producers in Nariño (Table 3).

Kouakou *et al.* (2015) reported in in Côte d'Ivoire a high level of literacy (81%) distributed in producers with primary level (32.1%) and university (36.6%). Other available data suggest that reading and writing skills among producers are significantly higher ($\geq$ 90%), compared with the territories of Kalehe (66.7%), Kabare (50%), and Walangu (58.8%) (Simtowe *et al.* 2017).

Illiteracy levels in producers of *C. porcellus* reported for Sub-Saharan Africa were 55% (Benin), 19% (Côte d'Ivoire), 29% (Cameroon) and 42% (Democratic

Republic of Congo) (Faihun *et al.,* 2017; Herman *et al.,* 2014; Mass *et al.,* 2016). These were considered high and constitute an obstacle to improved production (Ayagirwe *et al.,* 2018). In contrast, for the case of Colombia, illiteracy levels were distributed between 0% (Nariño) and 1% (Putumayo), which represents an opportunity for its improvement.

The area of *C. porcellus* systems in Colombia of 0.35 ha (Nariño) and 0.17 ha (Putumayo) is significantly smaller than that reported by Simtowe *et al.* (2017) for the Democratic Republic of Congo (1.8 ha). We observed that in Colombia the participating producers in the study fed *C. porcellus* mostly with locally available forage plants (67%) and few supplements (34%). Also, the use of concentrate has been widely used in locally developed experimental trials in feeding in the study area (Caycedo *et al.,* 2011) with low incorporation within the group of small producers (Cardona-Iglesias *et al.,* 2020; Patiño Burbano *et al.,* 2019). Our study coincides with the data available for Sub-Saharan Africa (Simtowe *et al.,* 2017) for countries such as Côte d'Ivoire (Kouadio Kouakou *et al.,* 2015), Democratic Republic of Congo (Kampemba *et al.,* 2017), and Tanzania (Maass *et al.,* 2016), where the use of concentrate is restricted and only applied in experimental trials, but generally not at the farm level.

Our analysis shows that the predominant species in the composition of diets corresponded to grasses (Poaceae), local forage resources (Asteraceae), tree resources, legumes (Leguminoseae) and kitchen waste. These results agree with a review article developed by Simtowe *et al.* (2017) in sub-Saharan African countries (Côte d'Ivoire, Benin, Cameroon, Gabon, Democratic Republic of Congo, and Tanzania) in which the authors reported that the predominant *C. porcellus*

Table 4. Multiple linear regression analysis

	Coefficients	SE	P <0.05	P-value regression	R-square
Independent variables				0.0004	0.0542
1. Demographics					
Gender	-0.265	0.1091	0.0156		
2. Production unit					
Origin of forage	0.2918	0.1071	0.0067		
Nutritional supplements	-0.2249	0.1134	0.0481		
Group you supplement	0.315	0.1382	0.0231		
3. Current technology					
Kitchen waste	-0.1885	0.0808	0.0202		
Fresh pasture mixtures	0.0663	0.1134	0.5587		
4. Projected technology					
Familiarization with fodder selection according to nutritional content	-0.132	0.1008	0.191		

feeding resources include grasses (Poaceae), herbaceous compounds (Asteraceae), legumes (Leguminosae), and kitchen waste (Ayagirwe *et al.,* 2018; Faihun *et al.,* 2017; Franklin *et al.,* 2017; Kampemba *et al.,* 2017; Kouadio Kouakou *et al.,* 2015; Ngoula *et al.,* 2017; Ngoupayou *et al.,* 1995; Simtowe *et al.,* 2017).

In the study area, the collected data reveal that forage comes from a low proportion of ancestral feeding practices such as collection in the fields or roadsides, being predominantly the implementation of small and large areas for the cultivation of fodder exclusively for *C. porcellus* feeding. In contrast, high forage collection in the fields and roadsides of the *C. porcellus* L. systems in sub-Saharan Africa, where the quantities collected depend on the carrying capacity of women. The results for the variable feeding frequency in the study area were coincident with available data to suggest that *C. porcellus* are generally fed one to three times a day without quantifying the amount (Simtowe *et al.,* 2017).

Within the feeding practices and use of technology in *C. porcellus* systems in Cameroon, most food sources come from agricultural waste and are sometimes supplemented with vegetables and fodder, resulting in low animal productivity (Niba *et al.,* 2012). In the Colombian case, the food base coming from harvest residues is used in a low proportion being predominantly the forage base. However, the results were a coincidence in terms of the low productivity presented by the animals belonging to small producers of *C. porcellus*. In this sense, at an experimental level, in order to contribute to the correct use of the species management, mixtures of forage and supplements that contribute to the improvement of productive parameters have been developed in different regions.

Emile *et al.* (2017) studied the voluntary consumption of fresh fodder in Cameroon with species such as *Cenchrus clandestinus* and *Pennisetum purpureum*. The voluntary consumption variable had significant differences when chopped *Pennisetum purpureum* was administered in contrast to unchopped *Pennisetum purpureum*. These same authors also reported that compared to the legumes evaluated, the level of crude protein and mineral in *Cenchrus clandestinus* and carbon in *Pennisetum purpureum* was high. Niba *et al.*

(2012) reported a high preference of *C. porcellus* L. for *Cenchrus clandestinus* compared to concentrate in Cameroon. In a study conducted in Ivory Coast, Kouakou *et al.* (2013) reported the use of *Panicum maximum* and *Euphoria heterofila* for the evaluation of *C. porcellus* meat quality. The association of *Panicum maximum* and *Euphoria heterofila* is reported to be a forage mixture that significantly improves digestibility, fecundity, birth weight and weaning weight in *C. porcellus* systems in the Democratic Republic of Congo (Bindelle *et al.,* 2007, 2009).

In the Colombian case, forage resources such as *Cenchrus clandestinus* and *Lolium sp.* have been used in mixture with concentrate in the phases of raising and fattening at an experimental level, obtaining a better productive behavior in terms of daily weight gain. During the fattening phase, experimental diets in vivo have been formed by *Cenchrus clandestinus*, *Phalaris arundinacea*, *Lolium multiflorum*, and *Trifolium repens*, in mixtures between *Cenchrus clandestinus* and *Trifolium repens* reporting high values of digestibility. The *C. porcellus* meat quality has been evaluated through supplementation with forage of *Acacia melanoxylon* and *Lolium hybridum*, consolidated as a recommendable alternative for increasing the content of fatty acids in meat.

Some experimental food supplements in Colombia have included the use of *Lupinus mutabilis* sweet, *Dahlia imperialis ortgies*, *Smallanthus pyramidalis*, and *Chenopodium quinoa willd*. Dietary supplements have integrated the use of *Avena sativa* hay, plant sources such as *Musa sapietum* L. flour, *Manihot Utilissima pohi* and *Saccharum officinarum L.*, *Brassica napus*, *Medicago sativa*, animal sources such as Californian red worm meal (*Eisenia foetida*), and blood meal. Other information available in Colombia suggests that the association of *Pennisetum sp.* and *Boehmeria nivea* should be valued for the improvement of the productive behavior.

Producers interviewed in both regions consider that the knowledge and incorporation in their systems of feeding practices and technology in nutrition and food based on local resources are promising opportunities to generate improvements in the productive process and income. The above coincided with what set out in the

Strategic Plan for Science, Technology, and Innovation (PECTIA) projected for the *C. porcellus* chain. We agree with what has been reported about the efforts of South–South cooperation between South America and Sub-Saharan Africa where it is considered a challenge to improve the supply of forage to achieve rapid and alternative access to food and income for women (Maass *et al.,* 2016).

Conclusions

The study population consisted of peasants and indigenous people from the Pastos, Inga and Kamëntsá ethnic groups, who see in the Andean ecosystem and in the practice of *C. porcellus* a strategy to reduce the impact on biodiversity, address climate change and generate regional sustainable development. This allows the integration of ancestral knowledge and scientific knowledge, in order to develop a strategy of food security proper to Family Agriculture, not only for subsistence, but also for systems that have had a medium to high level of technological development in the Andean mountains of Colombia. Our findings suggest that women in the study area are repositories of ancestral knowledge. It also reaffirms the role of women and her level of education in the family food security of the inhabitants of the Andes and in the incorporation of circular management technology that promotes bio-economic transition processes in the region.

Acknowledgments

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