https://doi.org/10.22319/rmcp.v12i2.5811

Article

Type and characterization of rabbit farmers in Mexico's central states

Alejandra Vélez Izquierdo [a]

José Antonio Espinosa García [a*]

Francisco Aguilar Romero [b]

[a] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP). Centro Nacional de Investigación Disciplinaria en Fisiología y Mejoramiento Animal. Km 1 Carretera a Colón, Ajuchitlán, 76280.Colón, Querétaro, México.

[b] INIFAP. Centro Nacional de Investigación Disciplinaria en Salud Animal. Palo Alto, Ciudad de México, México.

*Corresppnding author: espinosa.jose@inifap.gob.mx

Abstract:

This study aimed to identify and characterize the type of rabbit farmers in Mexico's central states based on social, productive, technological, economic, and efficiency factors; this information could help outline recommendations that support cuniculture practices. A survey was designed and applied to 155 rabbit production units (RPU) to obtain information about their socioeconomic, productive, and economic status; this survey also evaluated their use of facilities and technological components. Fourteen original variables were defined and helped stratify rabbit farmers through multivariate methods. The resulting groups were characterized and compared by analyzing variance following a completely randomized model for the continuous variables and a test of homogeneity for the categorical variables. Four factors accounted for 67.5 % of the total variation. Due to the factor loadings of the analyzed variables, these factors were identified as 1) productive capacity of the RPU, 2) technical capacity of the RPU, 3) farmer's capacity, and 4) technical efficiency of the RPU. Three types of producers were identified: small-scale family rabbit farmer (37 %), medium-scale family rabbit farmer (50 %), and business rabbit farmer (13 %). This typology could contribute to the outline of cuniculture-specific public policies to increase the efficiency and productivity of RPU in Mexico's central states.

Key words: Cuniculture, Stratification, Livestock technology, Technical efficiency.

Received: 21/09/2020

Accepted:03/12/2020

Introduction

Livestock production entails breeding animals for food or commercial purposes. In cuniculture, rabbits (*Oryctolagus cuniculus*) are used for their meat[1], which has nutritional characteristics with the potential to satisfy society's demand for meat with less fat and more protein. Rabbit's meat is lean, with a higher proportion of protein than other meats[2]. In Mexico, the federal government and academic institutions have encouraged cuniculture by creating promoting centers, distributing rabbit packages, and promoting rabbit meat consumption[3]. These activities have contributed to developing cuniculture practices in most Mexico's states, Michoacán, Mexico City, Puebla, and Hidalgo being the most important[4]. However, rabbit is a marginally exploited species[5].

In 2000, Mexico had 1'300,000 rabbits and produced 4,160 t of meat; by 2018, there were 1'407,000 rabbits and 4,483 t[6], with an average annual growth rate (AAGR) of 0.004 % from 2000 to 2018. Worldwide, Mexico ranks 13th and 19th in rabbit stock and production, respectively[6]. The rabbit meat per capita consumption in the country has been estimated at 100 g[4]. Countries like Portugal, France, Spain, and Italy consume two or more kilograms per person. In Mexico, cuniculture offers advantages that can be used in some regions to face the nutritional problems that affect low-income populations[5]. However, cuniculture depends on agro-ecological conditions, specific production systems, and the social, economic, and technological factors of the farmers. It is crucial to study these characteristics to understand their effect on productive processes and generate information supporting decision-making that contributes to cuniculture development.

There is a broad spectrum of methods and techniques to characterize and classify agricultural and livestock production systems. Among these techniques, multivariate analysis, such as the principal component analysis, factor analysis[7], and cluster analysis[8], stand out. However, few studies have evaluated the cuniculture activity in Mexico. A previous study with rabbit farmers from Tlaxcala reported the predominance of an extensive system, combined with characteristics from semi-intensive and business systems. Additionally, this study exposed some alternatives to improve the commercialization of rabbit meat(9). Another study interviewed consumers to identify their attribute preferences regarding the quality of rabbit meat. The authors reported that the most preferred attributes were organic, safety, freshness, and price(10). Other studies show experimental productive parameters using different diets in a rabbit farm in Hidalgo(11) and the economic outcomes with varying diets in a farm in Yucatán(12).

In Mexico, no previous studies have applied multivariate methods to evaluate cuniculture activities, such as the ones used to analyze the structure of sheep production systems and the type of sheep production units in Puebla and Tlaxcala(13), or the one used to characterize cattle production systems in the XIV Tulijá-Tseltal-Chol indigenous region in Chiapas(14), or the type of apiculturists in Morelos(15). Therefore, this study aimed to identify and characterize the type of rabbit farmers in Mexico's central states based on social, productive, technological, economic, and efficiency factors; this information could assist in the outline of recommendations that support cuniculture production.

Material and methods

Area of study and information source

The study was carried out in nine central states, characterized by a temperate climate and an altitude of more than 1000 masl: these states were: Mexico City, Guanajuato, Hidalgo, Jalisco, Mexico State, Morelos, Puebla, Querétaro, and Tlaxcala, which are the states with the highest number of rabbit female breeding stock(3). The information was obtained by designing and applying a survey to a significant sample of rabbit farmers. The survey included the following sections: i) socioeconomic data from the farmer and the RPU, which included the ten variables in Table 1; ii) technical -productive data from the RPU that included 12 variables shown in Table 1; iii) facilities, equipment, management variables, and technological components, integrated by the 24 variables shown in Table 2. The sample was taken from the PROGAN 2015 Register of SAGARPA (now SADER)(16). The sample size was determined following the maximum variance proportion sampling design(17):

$$n = \frac{N\,p(1-q)}{(N-1)\left(\frac{b}{Z_{1-a}}\right)^2 + p(1-q)}$$

Where *n* is the sample size; N is the population; Z represents the confidence level; β the precision level; *p* the probability that the sample is representative; and *q* the likelihood that the sample is not representative, with a confidence level of 90% (Z^2= 1.65) and a precision level of 14%. The estimated sample size *n* was 155 surveys, which represents 15 % of the population. Furthermore, the number of production units per state, the number of farms, and the total of average rabbits reported in the 2015 PROGAN registry shown in Table 3 were considered for sample distribution.

Table 1: Socioeconomic and technical variables of rabbit farmers in the central states of Mexico

Socioeconomic	Technical-productive
Gender: male and female	Number of breeding does
Experience (years of being a rabbit farmer)	Number of bucks
Age (years)	Number of kits
Schooling (years studied)	Number of fattening rabbits
Number of financial dependents	Number of kits per breeding doe per year
Land type: small property, *ejido*, communal land	Number of weaned kits per year Weaning age (days)
Other economic activities: none, salaried employee, eventual, commerce, agricultural, independent	Number of dead kits per year Number of discarded rabbits
Number of jobs (wages)	Number of sold kits per year
Family labor force (percentage)	Area for rabbits (m^2)
Contribution of cuniculture to income*	Area for slaughter (m^2)

* < 50%, > 50%, < 100%, and only income source.

Table 2: Facilities, equipment, management, and technological variables of rabbit farmers in Mexico's central states

Area	Variables
Facilities and equipment	1) Sanitizing mat: yes=1, no=0; 2) Warehouse: yes=1, no=0; 3) Water pump: yes=1, no=0; 4) Scale: yes=1, no=0; 5) Vehicle: yes=1, no=0; and 6) Refrigerator: yes=1, no=0.
Farm management	1) Technical records: yes=1, no=0; 2) Financial records: yes=1, no=0; 3) Rabbit batching: 0 no batching, 1 by age and sex, 2 by age, sex, and productive stage; 4) Practices discarding of unproductive breeding does: yes=1, no=0; 5) Practice manure management: yes=1, no=0; and 6) Processes meat: yes=1, no=0.
Reproduction and Genetics	1) Uses pure rabbit breeds: yes=1, no=0; 2) Uses registered studs: yes=1, no=0: 3) Evaluates bucks: yes=1, no=0; 4) Selects does: yes=1, no=0; 4) Selects bucks: yes=1, no=0; 5) Reproductive method: 1 Free breeding, 2 Controlled breeding; and 6) Performs gestation diagnosis: yes=1, no=0.
Feed:	1) Commercial feed: yes=1, no=0; 2) Prepares feed in the production unit: yes=1, no=0.
Sanitation	1) Internal deworming: yes=1, no=0; 2) External deworming: yes=1, no=0.
Technical consulting	1) Technical consulting: yes=1, no=0.
Use of facilities, equipment, and technological components	1) Sum of the positive data for the facilities, equipment, and technological component variables with a maximum value of 26.

Table 3: Number of production units, rabbitry structure, average surface area, and surveys applied to rabbit breeders in central Mexico

	CM	GTO	HGO	JAL	MEX	MOR	PUE	QRO	TLX
Farms	31	11	700	25	180	12	53	21	19
Breeding does	30	257	212	59	45	44	66	24	67
Kits	76	13	77	69	80	85	124	34	87
Fattening	72	13	62	69	58	95	67	58	164
Replacement	10	1	16	7	7	4	9	5	7
Bucks	5	96	17	8	7	4	6	3	9
Total	192	380	384	212	196	334	272	233	123
Surface area, m^2	0.03	4.27	0.66	2.4	9.54	0.42	6.79	2.58	4.57
Surveys	20	11	32	18	25	9	20	12	8

Source: Elaborated with data from the 2015 PROGAN Registry(16).

CM= Mexico City; GTO= Guanajuato; HGO= Hidalgo; JAL= Jalisco; MEX= Mexico State; MOR= Morelos; PUE= Puebla; QRO= Querétaro; TLX= Tlaxcala.

Information analysis

An exploratory analysis was carried out with basic and correlation statistics of the 46 variables considered for the study. Farmers were stratified with a multivariate analysis performed using factor analysis by principal components and hierarchical clusters. For the first analysis, 20 quantitative variables with positive correlation (P<0.05) were selected. Additionally, the quality, availability, and relevance criteria proposed by other studies were also applied[18,19]. The principal components with eigenvalues greater than one were rotated using the Varimax method to reduce the number of variables by building factors that explain the more significant variance in the global analysis[18,20]. The hierarchical cluster analysis was used to graphically identify the number of rabbit farmer clusters, based on the Ward algorithm[21,22] and the squared Euclidean distance[21,23], to recognize the cut-off point in the dendrogram (Figure 1). The factors obtained in the factor analysis by principal components were the variables employed and standardized with the mean and standard deviation. The statistical analyses were performed with the statistical program JMP® 9.0 (SAS Institute).

The means and standard deviations of the quantitative variables were calculated to characterize and compare the resulting clusters of rabbit farmers; additionally, an analysis of variance was carried out following a completely randomized model to detect differences between groups. As for the qualitative variables, it was calculated their frequencies and carried out a homogeneity test to identify differences between the clusters of rabbit farmers.

Results

Type of rabbit farmers in Mexico's central states

Based on the correlation matrix of the 46 variables mentioned in Tables 1 and 2, the 20 quantitative variables that had the highest correlations were selected and used in the multivariate analysis. Four factors were extracted from the factor analysis. These factors showed eigenvalues greater than one and explain 67.5 % of the total variation of the original variables. The factor loads that each variable has in the extracted factor with values greater than 0.50 allowed identifying the variables associated with said factor and thus facilitated an empirical interpretation and the assignment of a physical name.

Factor one is highly correlated with the surface area for the production and number of breeding does, sold rabbits, studs, weaned kits, and dead animals (Table 4). This factor was named *productive capacity of the rabbit production unit* and explained 29.3 % of the variance of the 14 variables. Thus, Factor 1 has the most influence on the analysis and better explains the differences between the clusters of rabbit farmers and their production scale. Factor 2 is highly correlated with the labor force in the farm, the surface area for rabbit slaughter, and the use of facilities, equipment, and technological innovations (Table 4). This factor was named *technical capacity of the rabbit production unit* and explained 14.7 % of the variance. Factor 3 is highly correlated with the social characteristics of the rabbit farmer, such as age, schooling, and years of experience in rabbit production. These variables define the production unit's ability to produce; therefore, this factor was named *capabilities of the rabbit farmer* and explained 11.6 % of the variance. Finally, Factor 4 has a high correlation with the number of kits produced per breeding doe per year, which evaluates the farm's productivity. Thus, this factor was named *technical efficiency of the rabbit production unit* and explained 10.6 % of the variation.

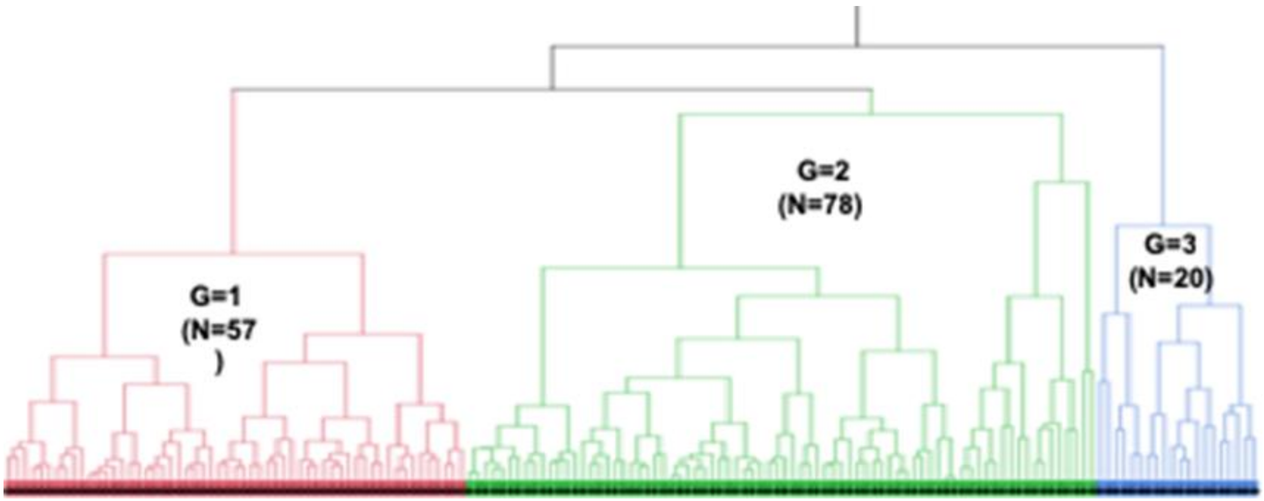
Table 4: Factor loadings of the variables that integrate the factors defined for the rabbit breeders of Mexico's central states

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Number of breeding does	**0.916667**	0.206498	0.035692	-0.032912
Number of sold kits/year	**0.83149**	0.228365	-0.041729	0.462372
Number of bucks	**0.816544**	0.167483	0.075937	-0.145468
Number of weaned kits/year	**0.799396**	0.258606	-0.062843	0.462191
Number of dead animals/year	**0.71444**	-0.046216	0.105208	0.287652
Area for rabbits	**0.642098**	0.181289	-0.008589	-0.087412
Use of facilities, equipment, and technological components	0.343973	**0.682402**	-0.013021	-0.048417
Labor force in the PU	-0.159698	**0.670922**	0.062029	0.219434
Schooling	0.171105	0.44837	**0.605979**	-0.072184
Area for slaughter	0.23495	**0.513992**	-0.125401	0.119383
Rabbit farmer's age	0.023885	-0.074193	**0.831125**	-0.084211
Years of experience in rabbit farming	0.141377	0.256117	**0.69565**	-0.003725
Number of kits per breeding doe/year	0.089981	0.098896	-0.05581	**0.927394**
Percentage of family labor force	-0.298046	**0.60223**	-0.176492	0.040382
Explained variance (%)	29.3	14.7	12.9	10.6

Values in bold represent the factor loadings of the variables that integrate each factor.

The information of the previously mentioned factors was included in the cluster analysis to identify the clusters of rabbit farmers by hierarchical analysis. Three types of rabbit breeders were graphically identified (Figure 1). The number of rabbit farmers in each group is G1=57 (37 %), G2=78 (50 %), and G3=20 (13 %).

Figure 1: Dendrogram of rabbit farmers in Mexico's central states



Each group was assigned a name based on the size of the production unit, the percentage of family labor force, and the use of facilities, equipment, and technological components (Table 5). Group 1 is integrated by producers with an average of 24 breeding does, with farms in which 91.5 % of the labor force are family members and use 60 % of the 24 variables related to facilities, equipment, and technological components. Thus, this group includes *small family rabbit farmers* (G1) with a medium technical level. Group 2 (G2) comprises producers with an average of 52 breeding does, with farms in which 87 % of the labor force corresponds to family members and use 67 % of the facilities, equipment, and technological components; thus, G2 includes *medium-scale family rabbit farmers*. Group 3 (G3) is integrated by producers with 55 breeding does, 40 % of the labor force is hired, and they use 88 % of the facilities, equipment, and technological components (of the 22 shown in Table 2); thus, G3 producers are considered *business rabbit farmers*.

Table 5: Mean ± standard error of the variables used to characterize the rabbit farmers in Mexico's central states

Factors	**Variables**	**Small-scale family rabbit farmer (G1)**	**Medium-scale family rabbit farmer (G2)**	**Business rabbit farmer (G3)**
1. Productive capacity	Number of breeding does	24.0±4.1[b]	51.5±3.5[a]	54.9±28.9[a]
	Number of sold kits/year	664.7±145[c]	1541.7±124[b]	2949.2±245[a]
	Number of bucks	2.7±0.5[b]	6.1±0.4[a]	6.1±0.9[a]
	Number weaned kits/year	571.3±132[c]	1,353.1±113[b]	2,596.8±223[a]
	Number of dead animals	93.4±23.8[b]	188.5±20.3[a]	252.4±40.1[a]
	Area for rabbits	55.3±11.8[b]	124.3±10.1[a]	108.4±19.9[ab]
2. Technical capacity	Use of facilities, equipment, and technological components	13.1±0.6[b]	14.8±0.5[b]	19.4±0.9[a]
	Labor force	1.5±0.1[b]	1.28±0.1[b]	3.3±0.2[a]
	Area for slaughter	1.1±1.1[b]	4.09±1.0[ab]	8.8±1.9[a]
	Percentage of family labor force	91.5±4.1[a]	86.5±3.6[a]	62.1±7.0[b]
3. Rabbit farmer capacities	Schooling	9.1±3.7[b]	13.4±0.4[a]	13.9±0.8[a]
	Age	54.3±9.5[a]	39.3±11.3[c]	46.5±13.5[b]
	Years of experience as a rabbit farmer	9.3±0.8[a]	6.2±0.7[b]	12.0±1.5[a]
4. Technical efficiency	Number of kits per breeding doe/year	29.5±1.7[b]	30.36±1.4[b]	52.0±2.8[a]

[ab] Different letters indicate differences based on an ANOVA and Tukey test (*P*<0.05).

Characterization by type of rabbit farmer

After defining the type of rabbit farmers, it was proceeded to characterize them based on the previously defined factors to identify the specific characteristics of each type of rabbit production unit, as previously carried out for other production systems[(15,18,19)]. Of the six variables included in Factor 1, *Productive capacity of the RPU*, two showed statistical differences (*P*<0.01) between the three types of producers. As for the remaining four variables, at least one of the groups was significantly different from the other two (*P*<0.05)

(Table 5). G1 producers show the lowest number of breeding does and studs and the smallest area for rabbit production. These data are directly related to the production scale of the RPU, reflected on the average of weaned and sold rabbits.

The number of weaned kits per year differed significantly between the three groups (F=31.7; gl=2, 152; P<0.01). The average value of G3 was significantly higher than the value of G2 (P<0.05), with a difference of 1,243 kits. Similarly, the value of G2 was significantly higher than the average value of G1 (P<0.05), with a difference of 782 rabbits (Table 5). Regarding the number of dead animals, it was observed significant differences (F=7.5; gl=2, 152; P<0.01) between groups. The average values of G2 and G3 were significantly higher than G1 (P<0.05). The area for rabbits showed the same behavior (F=10.8; gl=2, 152; P<0.01). Rabbit farmers in G2 and G3 had a significantly higher number of square meters than those in G1 (P<0.05).

The number of breeding does significantly differ between groups (F=15.1; gl=2, 152; P<0.01). The average values of G2 and G3 were significantly higher than G1 (P<0.05) (Table 5), with the double amount of breeding does. The number of rabbits sold per year differed significantly between the three groups (F=30.8; gl=2, 152; P<0.01); the average value of G3 was significantly higher than the value of G2 (P<0.05), with a difference of 1,308 rabbits. Similarly, the value of G2 was significantly higher than the average value of G1 (P<0.05), with a difference of 877 rabbits (Table 5). As for the number of bucks, it was observed significant differences between groups (F=13.1; gl=2, 152; P<0.01); the average values of G2 and G3 were significantly higher than G1 (P<0.05) (Table 5).

Regarding Factor 2, *Technical capacity of the RPU*, it was observed significant differences between groups in the use of facilities, equipment, and technology (F=16.5; gl=2, 152; P<0.01). The average value of G3 was significantly higher than the value of G1 and G2(P<0.05); there were no differences between these two groups (P<0.05) (Table 5). After analyzing the facilities and equipment included in this variable, it was found that two of the six explored concepts behaved differently between the groups; 70 % of the producers in G3, 31 % of G2, and 17.5 % of G1 use sanitizing mats (Xi^2=19.1; n=155; P<0.01). Similar behavior was observed regarding storage; 60 % of the rabbit farmers in G3 and less than 26 % of those in G1 and G2 had storage (Xi^2=14.5; n=155; P<0.01) (Figure 2).

Figure 2: Use of facilities, equipment, and technological components by rabbit farmers in Mexico's central states.

* Indicates statistical difference Prob > Chi-square 0.05.
** Indicates statistical difference Prob > Chi-square 0.01.

As for the technological components used by rabbit farmers, it was observed that 8 of the 18 analyzed activities behaved differently between groups. These components were: financial records, used by 65, 42, and 26 % of producers in G3, G2, and G1, respectively (Xi^2=9.9; n=155; P<0.01); rabbit batching, applied by 95, 74, and 65 % of producers in G3, G2, and G1, respectively (Xi^2=21.4; n=155; P<0.01); pure breeds, used by 85, 68, and 56 % of farmers in G3, G2, and G1 (Xi^2=5.8; n=155; P<0.05); registered studs, used by 40, 26, and 9 % of producers in G3, G2, and G1, respectively (Xi^2=10.4; n=155; P<0.01); stud evaluation, done by 45, 36, and 14 % of farmers in G3, G2, and G1 (Xi^2=10.5; n=155; P<0.01); internal deworming, carried out by 70, 54, and 39 % of farmers in G3, G2, and G1, respectively (Xi^2=7.3; n=155; P<0.02); external deworming, carried out by 90, 64, and 53 % of producers in G3, G2, and G1 (Xi^2=8.9; n=155; P<0.01); and technical consulting, received by 60, 38, and 26 % of producers in G3, G2, and G1 (Xi^2=7.4; n=155; P<0.02) (Figure 2).

Significant differences were also observed between groups in the total labor force variable (F=43; gl=2, 152; *P*<0.01). The average value of G3 was significantly higher than the value of G1 and G2 (*P*<0.05), and there were no differences between these two last groups (*P*<0.05) (Table 5). As for the area for slaughter, there were significant differences between the three groups (F=6.2; gl=2, 152; *P*<0.01). The area of G3 was greater than that of G2 (*P*<0.05), which was higher than the area of G1 (*P*<0.05). Furthermore, it was observed significant differences in family labor force (F=6.6; gl=2, 152; *P*<0.01); the average value of G3 was significantly lower than the values of G1 and G2 (*P*<0.05), and there were no differences between these last two groups (*P*<0.05) (Table 5).

Regarding the variables included in Factor 3, *rabbit farmer capacities*, it was observed significant differences between groups (F=25.5; gl=2, 152; *P*<0.01). The average value of G1 was significantly lower than the value of G2 and G3 (*P*<0.05), and there were no differences between these two groups (*P*>0.05) (Table 5). After analyzing the age variable (F=30.7; gl=2, 152; *P*<0.01), it was observed that producers in G1 were significantly older than those in G3 (*P*<0.05); moreover, G3 producers are older than those in G2 (*P*<0.05), more schooling and years of experience. Furthermore, it was observed significant differences (F=7.7; gl=2, 152; *P*<0.01) regarding the year of experience. Producers in G2 had significantly fewer years of experience than those in G1 and G3 (*P*<0.05), and there were no significant differences between G1 and G3.

Factor 4, *Technical efficiency of the RPU*, only includes one variable, production of kits per breeding doe per year, which was significantly different between groups (F=26.3; gl=2, 152; *P*>0.01). The average value of G3 was significantly higher than the value of G1 and G2 (*P*<0.05), and there were no differences between these two last groups.

Discussion

The four factors obtained from the factor analysis and identified as 1) *Productive capacity of the RPU*, 2) *Technical capacity of the RPU*, 3) *Rabbit farmer capacities*, and 4) *Technical efficiency of the RPU* explain 67.5% of the variation observed between the production units included in this study. This value is considered acceptable because, in social sciences, it is possible to consider solutions that represent 60 % of the total variance[24]. Additionally, this value is similar to that previously reported in Argentina (68 %) for the typification of farmers[25]. Therefore, these results can be considered reliable for inference.

The three categories used to classify rabbit farmers (small-scale family rabbit farmers, medium-scale family rabbit farmers, and business rabbit farmers), is pertinent, based on the participation of the family members in farm-related activities and the farm size(26). However, this classification differs from that reported for rabbit farmers in the state of Tlaxcala. This classification considers three production systems: backyard or extensive, semi-intensive, and intensive or businesses; the extensive rabbit production system predominate(9).

Three of the variables included in Factor 1 (*Productive capacity of the RPU*) are related to the size of the production unit; the remaining three variables are associated with rabbit production. Although these variables have not been previously studied, previous reports mention that the productive capacity of a production unit is mainly determined by its inventory(27), which includes machinery, equipment, constructions, and breeding female specimens. In the case of rabbit farming, this inventory is mainly constituted by breeding does and bucks. Thus, the amount of rabbit meat produced on a farm depends on the number of breeding does. This has been previously reported on other livestock species, such as dual-purpose cattle in the tropical region of Mexico(27) or beekeeping in Switzerland(28), in which the size of the production unit, measured as the number of colonies, was the factor that most affected honey production.

Other factors affecting production are the technological activities and components incorporated into the production unit(29). In rabbit farming, these innovations can include facilities, equipment, and technological components. The latter has been previously evaluated due to their effects on rabbit production. Rabbit batching has been studied by grouping, by age, litters of up to eight kits, which reduces mortality(30). These results have been acknowledged by the rabbit farmers in the central states of Mexico, as demonstrated by the percentage of batching use in the three groups of farmers (Figure 2). Additionally, similar results were observed regarding use of technical records in the producers of Tlaxcala (74 %)(9) and the rabbit farmers in the central states of Mexico.

The technological practices related to nutrition and reproduction are among the most evaluated in rabbit farming; this includes the use of commercial feed by itself or with diets added with local forage in the fattening of rabbits. No significant differences have been observed in productive parameters(11,31). This is why most of the producers in this study use commercial feed in their diets; this has also been reported for rabbit producers sin Tlaxcala. Together, these reports indicate that the basis of rabbit diets is commercial feed(9). The producers in G3 use pure breeds, although there is a technological margin because farmers are still not using registered bucks or evaluating them, especially farmers in G1. This situation matches the practices reported for the producers in Tlaxcala, where only 9.5 % selects breeding does(9).

It seems, no previous studies have quantified the presence of diseases and pests in rabbit farms. These studies only report the presence of viruses(10), although they do mention that the most frequent problems are pneumonia, mange, and enteritis. Therefore, 76.2 % of the producers in Tlaxcala carry out external deworming, similar to what was observed in the rabbit producers in central Mexico, especially those in G3, which indicates that this practice has already been incorporated into their production process.

The rabbit farmer and their family constitute the human capital of the RPU; this is considered a promoting factor for financial growth and development. The average values of the variables included in Factor 3 (*Rabbit farmer capacities*) were different for the three groups. The average age of the rabbit farmers in the three groups indicates that they are adults. Their age also influences the use and adoption of innovations; it is also an important factor to consider in the administrative and technical management of the production unit(15). Education level of rabbit farmers in G2 and G3 is upper secondary education (13 yr); farmers in G1 have secondary education (9 yr). These results are similar to the ones observed in previous studies(15). Still, they differ from the national situation, which indicates that 78.5 % of the rural population has no formal education, incomplete elementary school, or only elementary school(32). This situation stimulates the development of activities oriented to strengthen the production capacities of rabbit farmers in the three groups.

As for experience in rabbit farming, farmers in G3 had on average 12 yr of experience, those in G1 had nine years, and farmers in G2 had six years. G2 farmers are the youngest, with fewer years of experience and more years in education, which shows that rabbit farming is considered as an activity with potential(3,4). Although no previous studies have demonstrated the importance of social variables, such as age, schooling, or experience in the use of innovation and rabbit farming, various authors have reported(8,15,18) the importance of these variables as elements that favor or prevent the use of innovations.

The variables associated with Factor 4, *Technical efficiency of the RPU*, indicate both the productive and the technical capacities. The results reported for G1 and G2 are below the average values, 36 kits per breeding doe per year, reported for the rabbit production units in temperate regions(33). These results represent an opportunity for improvement if more technological components are incorporated, such as gestation diagnosis, registered bucks, buck evaluation, rabbit batching, and implementation of financial records.

Conclusions and implications

Three types of rabbit farmers were identified in Mexico's central states: small-scale family rabbit farmers (37 %), medium-scale family rabbit farmers (50 %), and business rabbit farmers (13 %). Farmers were classified and stratified based on the production unit's productive capacity, technical capacity, and technical efficiency, in addition to the farmer's capacity. The productive capacity of small-scale family rabbit farmers is lower than that of the other two groups because the number of breeding does is on average half of what the other groups have. However, their technical capacity and efficiency are similar to that of the medium-scale family rabbit farmers, which is less than observed in business farmers. Similarly, the percentage of the family labor force employed in the production unit predominates in the first two groups. These results will help propose recommendations to improve the productive capacity and the development of small-scale family rabbit farmers in central Mexico.

Literature cited:

1. Arrechedora I. Actividades pecuarias: Producción y actividades en México. https://www.lifeder.com/actividades-pecuarias/. Consultado 14 Sep, 2020.

2. Savino L. La carne de conejo, una buena opción para adquirir hábitos alimenticios saludables. Suena a Campo. Disponible: http://suenaacampo.com/2019/10/05/. Consultado 14 Sep, 2020.

3. SAGARPA-SENASICA. Manual de buenas prácticas de producción de carne de conejo. 1ª ed. Ciudad de México. 2015.

4. Comité Sistema Producto Cunícula. Plan rector sistema producto cunícola del Distrito Federal, actualizado a 2012. Ciudad de México.

5. Jaramillo VJL, Vargas LS, Guerrero RJ de D. Preferencias de consumidores y disponibilidad a pagar por atributos de calidad en carne de conejo orgánico. Rev Mex Cienc Pecu 2015;6(1):221-232.

6. FAOSTAT. Ganadería. Organización de las Naciones Unidas para la Alimentación y la Agricultura. Disponible: http://www.fao.org/faostat/es/#data/QC. Consultado 10 Sep, 2020.

7. Duvernoy I. Use of a land cover model to identify farm types in the Misiones agrarian frontier (Argentina). Agric Syst 2000;64(3):137-149.

8. Köbrich C, Rehman T, Khan M. Typification of farming systems for constructing representative farm models: two illustrations of the application of multivariate analyses in Chile and Pakistan. Agric Syst 2003;(76):141-157.

9. Olivares PR, Gómez CMA, Schwentesius RR, Carrera ChB. Alternativas a la producción y mercadeo para la carne de conejo en Tlaxcala, México. Región y Sociedad 2009;21(46):191-207.

10. Reynoso UE, Bautista GLG, Martínez CJS, Romero NC, García RVG, Aguado AGL, *et al*. Análisis de la presencia de Rotavirus en conejos del Estado de México. Rev Mex Cienc Pecu 2019;10(2):511-521.

11. Pérez MK, García VS, Soto SS, Zepeda BA, Ayala MM. Parámetros productivos de conejos alimentados con diferentes partes de la planta *Tithonia tubaeformis*. Abanico Veterinario 2018;8(2):108-114.

12. Peniche RJA, Rejón ÁMJ, Valencia HER, Pech MVC. Análisis de rentabilidad de dos alternativas de alimentación no convencionales en la producción de conejos en el municipio de Tixpehual, Yucatán, México. Rev Mex Agroneg 2010;XIV(27):411-418.

13. Vázquez MI, Jaramillo VJ, Bustamante GA, Vargas LS, Calderón SF, Torres HG, Pittroff, W. Estructura y tipología de las unidades de producción ovinas en el centro de México. ASyD 2018;(15):85-97.

14. Velázquez AJA, Raúl Perezgrovas GR. Caracterización de sistemas productivos de ganado bovino en la región indígena XIV Tulijá-Tseltal-Chol, Chiapas, México. Agrociencia 2017;(51):285-297.

15. Vélez IA, Espinosa GJA, Amaro GR, Arechavaleta VME. Tipología y caracterización de apicultores del estado de Morelos, México. Rev Mex Cienc Pecu 2016;7(4):507-524.

16. SAGARPA. PROGRAN Productivo de SAGARPA, datos 2015. https://datos.gob.mx/busca/dataset/. Consultado 14 Mar, 2016.

17. Infante GS, Zarate de LGP. Métodos estadísticos: un enfoque interdisciplinario. Colegio de Postgraduados. Mundi-Prensa España. 1990.

18. Fachini C, Firetti R, Cardoso DeOE, Assiz DeCA. Perfil da apicultura em Capão Bonito, estado de São Paulo: aplicação da análise multivariada. Rev Econom Agr 2010;57(1):49-60.

19. Gelasakis AI, Valergakis GE, Arsenos G, Banos G. Description and typology of intensive Chios dairy sheep farms in Greece. J Dairy Sci 2012;95(6):3070-3079.

20. Castaldo A, Acero R, Perea J, Martos J, Valerio D, Pami J, *et al*. Tipología de los sistemas de producción de engorde bovino en la Pampa Argentina. Arch Zootec 2006;55(210):183-193.

21. García CH, Calle LM. Consideraciones metodológicas para la tipificación de sistemas de producción bovina a partir de fuentes secundarias. Rev Corpoica 2013;2(2):6-15.

22. Hair JF. Multivariate data analysis. 7th ed. Upper Saddle River, NJ, USA: Pearson Prentice Hall; 2009.

23. Cuevas RV, Loaiza MA, Espinosa GJA, Vélez IA, Montoya FMD. Tipología de las explotaciones ganaderas de bovinos doble propósito en Sinaloa, México. Rev Mex Cienc Pecu 2016;7(1):69-83.

24. Valerio D, García A, Acero R, Castaldo A, Perea J, Martos J. Metodología para la caracterización y tipificación de sistemas ganaderos. Documentos de Trabajo Producción Animal y Gestión. Córdoba (España): Universidad de Córdoba. http://www.uco.es/zootecnia-ygestion/img/pictorex/14_19_10_sistemas2.pdf , Consultado 20 Ago, 2020.

25. Coronel DeRM, Ortuño PS. Tipificación de los sistemas productivos agropecuarios en el área de riego de Santiago del Estero, Argentina. Problemas del desarrollo. Rev Latinoam Econom 2005;36(140):63-88.

26. Schejtman A. Economía campesina: lógica interna, articulación y persistencia. Rev de la Cepal 1980;11(8):121-141.

27. Rangel RJ, Espinosa GJA, de Pablos C, Rivas J, Perea J, Angón E, García MA. Is the increase of scale in the tropics a pathway to smallholders? Dimension and ecological zone effect on the mixed crop-livestock farms. Spanish J Agr Res 2017;15(2):1-22.

28. Masuko MB. Socioeconomic analysis of beekeeping in Swaziland: A case study of the Manzini Region, Swaziland. J Develop Agr Econom 2013;5(6):236-241.

29. Kalenatic D, González L, López CA, Arias LH. El sistema de gestión tecnológica como parte del sistema logístico en la era del conocimiento. Cuadernos de administración 2009;22(39):257-286.

30. González RP, Negretti P, Finzi A. Adopción de gazapos a diferentes tamaños de camada en un sistema alternativo de producción de conejos. Agrociencia 2010;44(3):275-282.

31. Bonilla VCE, Delgado ALA, Mora LRE, Herrera AAM. Efecto de niveles crecientes de follaje de *Arachis pintoi* en dietas para conejos sobre el desempeño zootécnico en fase de crecimiento-engorde. Rev Científica FCV-LUZ 2016; XXVI(1):41-48.

32. FAO-SAGARPA. Diagnóstico del sector rural y pesquero de México 2012. Disponible: https://www.agricultura.gob.mx/sites/default/files/sagarpa/document/2019/01/28/1608/01022019-1-diagnostico-del-sector-rural-y-pesquero.pdf. Consultado 27 Nov, 2020.

33. Cruz BLE, Ramírez VS, Vázquez GM del C, Zapata CCC. Reproducción de conejos bajo condiciones tropicales, efectos negativos y posibles soluciones. Ciencia UAT 2018; 13(1):135-145.