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CHARACTERISTICS OF RABBIT FARMS IN SOUTHERN BENIN

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Abstract

The aim of this study was to provide a comprehensive analysis of rabbit farming in southern Benin. A thorough survey was carried out on a total of eighty (80) rabbit farms, and the data collected from these farms were then analyzed. As a result of this analysis, three (03) distinct groups of farmers were identified and characterized. Group 1 consisted of rabbit farmers who possessed more a university-level education. These individuals raised their rabbits in cement-built structures, in structures constructed from wood, earthen materials, or metal and mainly encountered pathological problems. Group 2 consisted of individuals with a primary level of education, possessing basic literacy skills, and maintaining rabbits in wooden structures. The farmers within this group encountered issues pertaining to pathology, feeding, habitat and waste management. Group 3 consisted mainly of rabbit breeders with varying levels of education, ranging from primary to university-level. These farmers housed their rabbits in structures constructed from cement and metal. The farmers within this group encountered issues pertaining to pathology, feeding and waste management. The predominant material used for the cages was metal, accounting for 93.7% of the cages, while nest boxes were found in 95% of these cages. The rabbits were provided with concentrated feed, occasionally supplemented with forage, by the farmers. However, they encountered various challenges primarily linked to diseases and feeding practices. Gastroenteritis, scabies, and viral hemorrhagic disease (VHD) were among the most common diseases that negatively impacted farm productivity. The occurrence of these diseases significantly diminished the numerical productivity of the farms, resulting in an inadequate production to satisfy the demand. As a consequence, selling products like live rabbits and rabbit carcasses became more convenient for the farmers. In conclusion, in order to effectively address the challenges that impede the development of rabbit farming in groups 2, it would be advantageous to consider implementing additional enhancements in practices.

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Introduction

In Benin, while the rearing of ruminants is predominantly concentrated in the northern regions of the country, the production of rabbits is more extensively developed in the southern areas (Yo et al. 2018). Meat production in Benin was estimated to reach 108, 034 tons in 2023 according to DSA (2024). However, this amount would provide 7.5 g of protein per person per day, which is below the estimated global animal protein consumption need of 24 g per person per day (FAOSTAT 2024). To meet the high and growing demand for animal proteins, Benin is forced to import meat through economic operators, resulting in a significant loss for the local economy. To reduce these imports, it is necessary to increase national meat production and thus among other measures to develop short-cycle species such as small ruminants, pork, poultry, and rabbits. Among these species, the rabbit *(Oryctolagus cuniculus*) is the animal resource of first choice due to the ease with which it can be reared, its short life cycle and its prolificacy (Djago et al. 2010). A female rabbit can give birth to around 40 young rabbits a year, providing 50 to 60 kg of meat a year for sale (Djago et al. 2010).

Rabbit farming in Benin has experienced significant growth over the past two decades, thanks to the widespread adoption of technological innovations resulting from research conducted by the Centre Cunicole de Recherche et d'Information (CeCURI) (Kpodekon et al. 2018). These endeavors have facilitated the creation of habitats that adhere to standards and are well-suited for tropical conditions. Additionally, it has facilitated the implementation of sanitary and medical prophylaxis programs and feed formulas tailored to the physiological stages of these animals (Djago et al. 2010; Kpodekon et al. 2018; Mensah et al. 2019). Regarding reproduction management, the previous studies evaluated rabbit performance to determine the ideal breeding periods and selection criteria of animal for breeding (Koutinhouin et al. 2009; Kpodekon et al. 2018). In genetics, the local breed animal performance has been improved through crossbreeding and selection (Akpo et al. 2018; Dotché et al. 2018). Finally, to ensure successful product marketing, the quality of rabbit meat has been improved and factors that may compromise it have been studied (Kpodékon et al. 2008; Tougan et al. 2019; Adogoni et al. 2021). These efforts have resulted in increased productivity of rabbit farms in southern Benin. Unfortunately, from 2015 to the present day, the emergence of VHD in rabbit farms has caused disruption in the technical and economic management of these farms, resulting in a decrease in animal productivity. In order to enhance resilience against factors impacting productivity, rabbit farmers in Benin frequently adapt their breeding practices. A study undertaken in 2018 following several outbreaks of VHD by Yo et al. (2018) identifies a number of challenges to the development of rabbit farming in Benin. These challenges encompass the enhancement of the genetic level of the rabbit breeds raised, the improvement of biosecurity measures on farms, the facilitation of farmers' access to reasonably priced feed, the optimisation of the marketing of rabbits produced, and the revitalisation of rabbit farming following episodes of VHD. The identification of a typology of farms is recommended in order to address the difficulties involved in meeting these challenges, given that not all farms have the same practices or face the same problems. Some studies have already examined farm typology, and several types have been described (Medenou et al., 2020; Konmy et al. 2023). The typology developed by Medenou et al. (2020) places particular emphasis on economic and social dimensions. In addition to livestock farming practices, the typology developed by Konmy et al. (2023) addresses diseases and their treatment. The main shortcoming of the types of farming identified in the preceding

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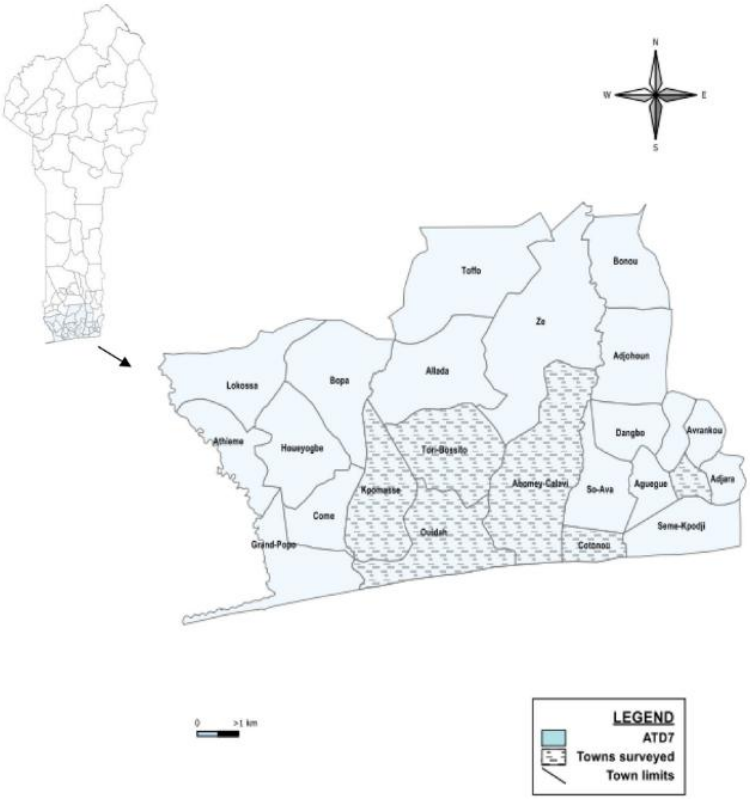
studies is that the difficulties encountered by farmers were not taken into account, which makes it difficult to propose improvements adapted to each type.In addition, these studies did not report data on rabbit performance, which means that the impact of difficulties on farm productivity cannot be properly assessed. This study aims to typify local rabbit farming systems and conduct a comparative analysis to highlight the strengths and weaknesses of each approach. The ultimate goal is to formulate recommendations that can enhance the productivity of these farms .

Materials and methods

STUDY AREA

The Republic of Benin is located between 6°30' and 12°30' North latitude and 1° and 3°40' East longitude. It has a surface area of 114,763 km² and shares borders with the Atlantic Ocean to the south, Togo to the west, Nigeria to the east, Niger to the northeast, and Burkina Faso to the northwest. Benin is divided into twelve departments. The study was conducted in Southern Benin, specifically in the Departments of Atlantique, Littoral and Ouémé (Fig. 1). The selection of these regions was predicated on their status as areas of high rabbit production in Benin (Yo et al.,, 2018). The study area has a sub-equatorial climate with two rainy seasons alternating with two dry seasons. The long rainy season lasts from March to July, while the short rainy season covers September and October. Rainfall ranges from 900 mm to 1,500 mm per year, and temperatures fluctuate between 25 °C and 30 °C. In southern Benin, the local population engages in fish, small-scale goat, sheep, and rabbit farming (INSAE 2015).

Fig. 1 Study area on rabbit breeding characteristics in southern Benin



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DATA COLLECTION

Data on the characteristics of rabbit farms in southern Benin were collected from 80 rabbit breeders. They were selected from a list provided by the management of the Agence Territoriale de Développement Agricole Pôle 7 and were interviewed using a survey form with semi-closed questions about their social characteristics and breeding practices. The selection of farmers was based on the availability of rabbits at the time of the study. It should be noted that some of the farmers on the list were not in possession of any animals at the time of data collection due to recent diseases. The survey sheet contained information on the respondent's surname, first names, level of education, gender, and marital status. It also included details on production objectives, animal acquisition methods, animal management practices, types, and construction materials, breeds or genetic types raised, housing hygiene, feed types, reproduction selection criteria, culling criteria, breeding age, farm management, animal marketing, and diseases and difficulties encountered by farmers.

Following the interview with the farmer, the respondent's farm was visited to take an inventory of the animals present, including the herd structure, and to collect data on reproductive performance. The inventory involved counting the number of bucks and does, young rabbits, rabbits being fattened, and rabbits selected for reproduction. To evaluate reproductive performance, data were collected on litter size at birth, number of live births, number weaned, and litter rank from suckling rabbits on the farms. These data were supplemented with existing information collected from farmers. The collected data was then recorded in a database and used to determine the rates of liveborn, stillborn, and weaned animals using the following formulas:

$$\text{Stillborn}rate = \frac{Numberofstillborn}{Totalnumberofrabbitsborn} \times 100$$

$$\text{Bornalive}rate = \frac{Numberofrabbitsbornalive}{Totalnumberofrabbitsborn} \times 100$$

$$Weaningrate = \frac{Weanednumberat33days}{Numberofrabbitsbornalive} \times 100$$

STATISTICAL ANALYSIS

The data were analyzed using SAS software (SAS Institute Inc., Cary, NC, USA) and R4.0.2 (Core Team 2020). Multiple correspondence analysis (MCA) was performed using the FactoMineR' library (Husson et al. 2016; Cornillon et al., 2018) on the following variables: level of education, types of habitats used, manure management on the farm, rabbit marketing, and difficulties encountered. A hierarchical ascending classification of farm characteristics based on the most significant components of the MCA was performed using R's Hierarchical Classification on Principal Components function. Identified farmers groups were then compared using Chi² test performed with the PROC FREQ procedure of SAS for qualitative variables. The bilateral Z-test was used to compare the relative frequencies between the groups. For each relative frequency, a 95% confidence interval (CI) was calculated using the formula:

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$CI = 1.96\sqrt{\frac{[P(1-P)]}{N}}$, Where P is the relative frequency and N is the sample size.

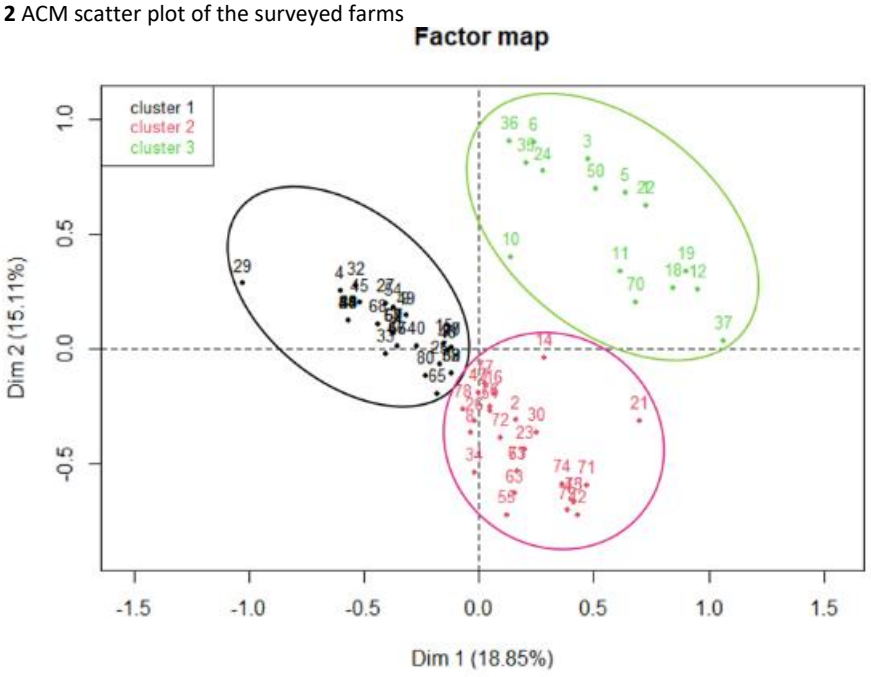
An analysis of variance was carried out using the PROC GLM procedure in SAS for the quantitative variables, including herd structures, reproductive performance and product prices. The only factor considered in the model was the types of farms. The significance of this group effect was determined using the Fisher test, and pairwise comparisons between group means were made using the Student's t-test.

Results

TYPOLOGY OF RABBIT FARMS IN SOUTHERN BENIN

The results of the Multiple Correspondence Analysis (MCA) were interpreted using the first three axes. The total inertia of these three axes is 44.8%, with 18.8% on the first axis, 15,10% on the second axis, and 10,9% on the third axis. An ascending hierarchical classification identified three groups. Groups 1 and 3 farmers were separated from those in group 2 by the first axis, while the second axis distinguished farmers in groups 2 and 3 from those in group 1 (Fig. 2).

Fig. 2 ACM scatter plot of the surveyed farms



Group 1 comprised farmers with either a secondary school or university-level education. These farmers had built animal housing using wood, cement and other materials. The hygiene standards within these dwellings were considered acceptable to good. Farms that were deemed to have acceptable hygiene and biosecurity practices were characterized by clean cages, drinkers, and feeders, although the buildings themselves were often dirty. While foot baths were provided, they were not maintained in a clean condition. Farms with good hygienic and biosecurity practices were those with clean buildings,

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cages, and feeding and drinking troughs. Farmers in this group primarily used well and borehole for the care of their rabbits, but frequently encountered difficulties in relation to feeding and disease management. Rabbits are removed from farms as soon as they reach the weight required for slaughter and sale, and as soon as they reach culling age. In this group, animals were only removed in cases of diseases, celebrations, ceremonies, or donations. These farmers utilized the rabbit manure either as fertilizer for the soil or donated them to other farmers and gardeners.

Group 2 comprised farmers with primary school level or no formal education. They housed their rabbits in either wooden or other materials buildings. The hygiene standards in their facilities varied from average to poor. Farms with poor hygiene and inadequate biosecurity practices were identified by dirty buildings, drinkers, feeders, and cages. These farms did not implement foot baths. The breeders provided rabbits with well drinking water, but often encountered difficulties. These difficulties include the presence of disease, food problems, housing problems and waste management problems. Rabbits that fell ill were not sold, and there were fewer rabbits available for donation. The rabbit droppings were either sold or discarded.

Group 3 comprises farmers with university, primary school and secondary level education. They housed their rabbits in wooden or cement materials buildings. The hygiene standards within these dwellings were considered acceptable. The farmers provided rabbits with well drinking and borehole water, but frequently encountered difficulties in relation to feeding, disease and waste management. Rabbits that fell ill were not sold, and there were fewer rabbits available for donation. The rabbit droppings were either sold or distributed to other users.

FARMER PROFILE AND RABBIT PRODUCTION OBJECTIVES IN SOUTHERN BENIN

Table 1 presents the results on the farmers's profile categorized by gender, level of education, and marital status. Rabbit farming was predominantly practiced by men (83.7%) compared to women (16.3%) in the study area. The majority of farmers were married (71.3%), although a small percentage were unmarried (27.5%) and a smaller percentage were widowed (1.2%) ($p < 0.05$). Regarding the level of education, 56.3% of the surveyed farmers have a university degree. The following maximal educational levels were secondary and primary education, with proportions of 23.8% and 15.0% respectively. Rabbit farming was practiced by very few out of school or literate farmers. To begin breeding, most farmers (98.8%) purchased local breed rabbits (65%) and hybrids (70%) (Table 2). In terms of production objectives, farmers produced significantly more for sale (97.5%) than for consumption (48.8%), savings (3.8%), or ceremonies (1.3%) ($p < 0.05$).

The proportions of male and female farmers in the three groups varied significantly. Group 1 had a higher proportion of men (94.4%) compared to groups 2 (73.1%) and 3 (75%). The proportion of men and women in group 2 was not significantly different from that of group 3. In regard to the level of education, only a university education exhibited variation between the groups. The proportion of farmers in group 1 (71.1%) who possessed a university degree was significantly higher ($p < 0.05$) than those in group 2 (34.6%).

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Table 1 Social profile of rabbit breeder farmers surveyed in Southern Benin

Variables	General (*N*=80)		Group 1 (*N*=38)		Group 2 (*N*=26)		Group 3 (*N*=16)		*P*>Chi²
	%	CI	%	CI	%	CI	%	CI	
Gender									
Men	83.8^{α}	8.1	94.7^{a}	7.1	73.1^{b}	17.0	75^{b}	21.2	*
Woman	16.3^{β}	8.1	5.3^{b}	7.1	26.9^{a}	17.0	25^{a}	21.2	
Education level									
Out of school	3.8^{δ}	4.2	0	0	11,5	12.3	0	0	NS
Literate	1.2^{δ}	2.4	0	0	3,9	7.4	0	0	NS
Primary	15^{β}	7.8	0^{b}	0	34.6^{a}	18.3	18.8^{a}	19.1	**
Secondary	23.8^{β}	9.3	28.9	14.4	15.4	13.9	25.0	21.2	NS
University	56.3^{α}	10.9	71.1^{a}	14.4	34.6^{b}	18.3	56.3^{ab}	24.3	*
Marital status									
Married	71.3^{α}	9.9	81.6	12.3	65.4	18.3	56.3	24.3	NS
Single	27.5^{β}	9.8	18.4	12.3	30.8	17.7	43.8	24.3	NS
Widower	1.2^{δ}	2.4	0.0	0.0	3.9	7.4	0.0	0.0	NS

** : p<0.05; ** : p<0.01; NS :p>0.05; CI : Confidence Interval, N : Number; $^{a, b}$percentages on the same line followed by the different letters differ significantly at the 5% threshold (for between-group comparison); $^{\alpha, \beta, \delta}$percentages within a class on the same column followed by the different symbolsdiffer significantly at the 5% threshold (for overall percentage)*

Table 2 Production objectives and breeding stock acquisition methods of rabbit breeder farmers surveyed in Southern Benin

Variable	Percentage (*N*=80)	Confi-dence interval
Production targets		
Consumption	48.7^{β}	10.9
Sales	97.5^{α}	3.4
Savings	3.8^{δ}	4.2
Ceremony	1.2^{δ}	2.4
Acquisition mode		
Purchase	98.7^{α}	2.4
Donation	3.8^{β}	4.2
Entrusted	1.2^{β}	2.4
Breed types		
Local	65^{α}	10.4
Hybrids (Local * Exotic)	70^{α}	10

N: Number; $^{\alpha, \beta, \delta}$intra-class percentages in the same column followed by the different symbols differ significantly at the 5% threshold

ANIMAL HABITATS AND BIOSECURITY ON RABBIT FARMS

Table 3 shows that The majority of farmers surveyed (98.75%) had dwellings, constructed from wood (46.15%), bricks (32%), and other materials such as racks, metal sheets, palm or coconut branches (28.2%), and with tin roof (93.3%). The farmers used metal cages to house their rabbits, with nest boxes inside (95%). The cages complied with standards in terms of dimensions for 90% of farmers. In terms of hygiene, the majority of farmers (76.2%) had acceptable hygiene on their farms (Table 3). The study found that rabbit droppings were commonly used as a fertilizer for soil, with a significantly higher proportion of people using them for this purpose compared to those who sold, donated, or discarded them ($p < 0.05$). In cases of animal mortality, the carcasses were either buried directly (60%), thrown into a pit (37.5%), or consumed (8.7%).

The utilization of wooden habitats was found to be more prevalent ($p < 0.05$) in group 2 compared to groups 1 and 3. Conversely, farmers in group 3 exhibited a higher frequency of utilization ($p < 0.05$) of cement-built hard habitats compared to those in the other groups. The proportion of farmers in group 1 (35.1%) who used cement housing was significantly higher ($p < 0.05$) than in group 2 (12.7%). The use of these droppings to fertilize the soil was significantly higher in groups 1 (79%) and 3 (62.5%)

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compared to group 2 (19.2%) ($p < 0.001$). Conversely, manure was more commonly sold and discarded in group 2 than in groups 1 and 3 ($p < 0.001$) (Table 4).

Table 3 Habitat and housing for rabbits from rabbit breeder farmers surveyed in Southern Benin

Variable	*N*	Percentage	Confidence interval
Presence of habitat for rabbits			
Yes	80	98.75^{α}	2.4
No	80	1.25^{β}	2.4
Wall building materials			
Wood	78	46.15^{α}	11.1
Cement wall	78	$32.05^{\alpha\beta}$	10.4
Other	78	28.21^{β}	10
Roof			
Sheet metal	78	92.31^{α}	5.9
Straw	78	1.28^{β}	2.5
No	78	2.56^{β}	3.5
Other	78	3.85^{β}	4.3
Cage types			
Metal	80	93.75^{β}	5.3
Concrete bar	80	100^{α}	0
Wood	80	11.25^{δ}	6.9
Presence of nest boxes			
Inside cages	80	95^{α}	4.8
Outside cages	80	3.75^{β}	4.2
No	80	1.25^{β}	2.4
Cage dimensions			
Respected	80	90^{α}	6.6
Not Respected	80	10^{β}	6.6
Hygiene on the farm			
Good	80	16.25^{β}	8.1
Acceptable	80	76.25^{α}	9.3
Bad	80	7.5^{β}	5.8

N : Number,$^{\alpha, \beta, \delta}$intra-class percentages on the same column followed by the different symbols differ significantly at the 5% threshold

Table 4 Waste and dead animals management of rabbit breeder farmers surveyed in Southern Benin

Variables	General (*N*=80)		Group 1 (*N*=38)		Group 2 (*N*=26)		Group 3 (*N*=16)		Chi²
	%	CI	%	CI	%	CI	%	CI	
Waste management									
Soil fertilization	56.2^{α}	10.9	79^{a}	13	19.2^{b}	15.1	62.5^{a}	23.7	***
Sales	27.5^{β}	9.8	5.3^{c}	7.1	61.5^{a}	18.7	25^{b}	21.2	***
Donation	26.3^{β}	9.6	29	14.4	15.4	13.9	37.5	23.7	NS
Discarded	17.5^{β}	8.3	2.6^{b}	5.1	38.5^{a}	18.7	18.8^{a}	19.1	***
Corpse management									
Consumption	8.7^{δ}	6.2	10.5	9.8	12.0	12.7	0	0	NS
Thrown into a pit	37.5^{β}	10.6	44.7	15.8	42.3	19	12.5	16.2	NS
Buried	60^{α}	10.7	51.4	16.1	61.5	18.7	81.3	19.1	NS
Other	15^{δ}	7.8	21.1	13.0	3.9	7.4	20.0	20.2	NS

**** : p<0.001; N : Number; NS: Not significant; CI: Confidence Interval,$^{a, b, c}$percentages on the same line followed by the different letters differ significantly at the 5% threshold (for between-group comparison);$^{\alpha, \beta, \delta}$intra-class percentages on the same column followed by the same symbol do not differ significantly at the 5 threshold (for overall percentage)*

FEEDING RABBITS ON FARMS

All surveyed farmers used concentrates feeds in pellet form. Breeders purchase complete feeds commercially, primarily from Véto Service. The composition of these feeds varies depending on the physiological stage and age of the animals. Traders provide feed for fattening and suckling females. Of these, 82.5% used forage as a feed supplement (Table 5). The forages used were diverse, but the most

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frequently cited by farmers were *Moringa oleifera*, *Tridax procumbens and Ocimum gratissimum* (Table 6). In rabbit watering, well water was used by farmers more frequently (57.5%) than borehole water (36.3%) and river water (1.25%) ($p < 0.05$).

Table 5 Rabbit feed offered by rabbit breeder farmers surveyed in Southern Benin

Variable	Percentage ($N=80$)	Confidence interval
Food types		
Complete foods	100^{α}	0
Forages	82.5^{β}	8.3
Mixture of a few raw materials	1.2^{δ}	2.4
Water source		
River	1.2^{γ}	2.4
Borehole/drilling	36.3^{β}	10.5
Well	57.5^{α}	10.8
Other	10^{δ}	6.6

N : Number; $^{\alpha, \beta, \delta, \gamma}$*Intra-class percentages in the same column followed by the different symbols differ significantly at the 5% threshold*

Table 6 Forages used in rabbit feed from rabbit breeder farmers surveyed in Southern Benin

Scientific name	Part used	Percentage	Confidence interval
Moringa oleifera	Leaves	69.7^{α}	11.1
Manihot esculenta	Leaves	3^{γ}	4.1
Carica papaya	Leaves	6.1^{γ}	5.8
Musa sp	Leaves	3^{γ}	4.1
Elaeis guineensis	Leaves	42.4^{β}	11.9
Azadirachta indica	Leaves	7.6^{γ}	6.4
Tridax procumbens	Leaves	19.7^{δ}	9.6
Lactuca sativa	Leaves	6.1^{γ}	5.8
Cola acuminata	Leaves	1.5^{γ}	2.9
Daucus carota	Leaves	4.5^{γ}	5
Ipomea aquatica	Leaves	1.5^{γ}	2.9
Vernonia amygdalina	Leaves	3^{γ}	4.1
Ocimum gratissimum	Leaves	12.1^{δ}	6.9

$^{\alpha, \beta, \delta, \gamma}$*percentages on the same column followed by the different symbols differ significantly at the 5% threshold*

There was no significant difference in the proportions of farmers using forage in the three groups. The percentage of farmers in groups 2 and 3 using borehole water was significantly higher ($p < 0.05$) than those in group 1.

REPRODUCTION MANAGEMENT ON RABBIT FARMS

LIVESTOCK STRUCTURE

On the surveyed farms, the average number of rabbits was 88.6 ± 15.3, consisting of 15 females' reproducers and 3 males' reproducers. The remaining herd comprised young rabbits under mother's milk, young rabbits for fattening, and young rabbits selected for breeding (Table 7). Notably, the number of young females between weaning at 33 days and breeding in group 3 (5.6 head) was significantly higher ($p < 0.05$) than in group 1 (1.6 head).

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Table 7 Livestock structure of rabbit breeder farmers surveyed in Southern Benin *N: Number*

Variable	Average (*N* = 80)	Standard error
Reproducer male	3.1	0.3
Reproducer female	14.9	1.7
Young rabbits (unweaned)	30.4	4.5
Young male (weaning-breeding)	0.6	0.2
Young male for fattening	18.8	5.3
Young male in breeding	2.0	0.8
Young female (weaning-breeding)	3.8	0.7
Young female for fattening	20.2	4.2
Young rabbit in breeding	7.6	2.4
Total livestock	**88.6**	15.3

N: Number

Table 8 Selection criteria for male and female breeding stock performed by rabbit breeder farmers surveyed in Southern Benin

Variables	Percentage (*N* = 80)	Confidence interval
Males		
Breed	37.5^{δ}	10.6
Growth	56.3^{β}	10.9
Relationship	21.3^{γ}	9
State of health	$41.3^{\beta\delta}$	10.8
Conformation	73.7^{α}	9.6
Coat colour, eye colour, original litter size	36.3^{δ}	10.5
Females		
Breed	36.7^{δ}	10.6
Growth	$54.4^{\alpha\beta}$	11
Relationship	$45.6^{\beta\delta}$	11
State of health	$43.0^{\beta\delta}$	11
Conformation	65.8^{α}	10.5
Number of nipples	18.9^{γ}	8.6
Coat colour, eye colour, original litter size	20.2^{γ}	8.9

N: Number, $^{\alpha, \beta, \delta, \gamma}$*intra-class percentages on the same column followed by the different symbols differ significantly at the 5% threshold*

CHOICE OF BREEDING STOCK

Male sires were chosen by breeders based on various criteria, including conformation, growth performance, health status, breed, parentage, and other factors (Table 8). Conformation (73.7%) and growth (56.2%) were the most used criteria, with significantly higher frequencies ($p < 0.05$) than other criteria. Kinship was the least used criterion. The selected males were used to mate female at 5.20 months of age. Farmers used the same criteria to select females for breeding. Conformation was the primary criterion for 65.8% of farmers, while the number of teats was the least one. The selection criteria did not vary significantly between groups.

On average, the selected females were mated for the first time at 4.7 months of age. Regarding gestation, female rabbits gave birth 30 days after mating (Table 9). The bunnies were weaned at 32.98 days and the females mated again 9.5 days after weaning. The animals that were not selected for breeding were fattened and sold for human consumption. The average duration of fattening was 2.8 months.

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Table 9 Zootechnical parameters of local rabbits from rabbit breeder farmers surveyed in Southern Benin

Variable	Mean	Standard error
Age of males at breeding (mo)	5.2	0.1
Age of female at breeding(mo)	4.7	0.1
Weaning age (d)	32.9	0.7
Fattening duration (mo)	2.8	0.1
Weaning-mating interval (d)	9.5	0.8
Gestation period (d)	30.1	0.1

mo: month; d: day

CULLING OF REPRODUCER

Criteria for culling breeding stock were based on objective factors such as reduced litter size, loss of libido in males, high bunnies' mortality at birth, locomotion problems, and parity rank in females. Female rabbits were culled if they give birth to less than five rabbits in three consecutive litters, have three stillbirths per litter out of three births, or suffer from leg pain. Male rabbits were culled if they experienced a loss of libido or develop leg pain. The most frequently used criterion by almost all farmers ($p < 0.05$) was reduced litter size (94.2%), followed by loss of libido in males (66.7%) and high mortality rate of young at birth (63.8%). Out of the four criteria used by farmers, locomotion problems were applied by 24.6% of farmers (Table 10). Additionally, parity rank was the least used criterion, with only farmers in group 1 applying it. The criteria used to select reproducers did not vary significantly between groups.

Table 10 Culling breeding stock on rabbit farms by rabbit breeder farmers surveyed in Southern Benin

Variable	Percentage (N=80)	Confidence interval
Culling criteria		
Loss of libido	66.7^{β}	11.1
Locomotion problems	24.6^{δ}	10.2
Reduced litter size	94.2^{α}	5.5
High birth mortality among young rabbits	63.8^{β}	11.3
Parity rank	1.4^{γ}	2.8
Culling ages		
1 year	33.3^{β}	11.1
2 years	73.9^{α}	10.4
3 years	17.4^{δ}	8.9

$^{\alpha, \beta, \delta, \gamma}$*intra-class percentages on the same column followed by the different symbol differ significantly at the 5% threshold*

It is worth noting that 73.9% of surveyed farmers cull their breeding stock at two years of age. However, some farmers cull their animals at one year of age for various reasons, while others choose to cull at three years of age (17.4%).

FARM PRODUCTIVITY

The mean litter size at birth was 6.7. The number of live births was 6.24, and the number of weaned rabbits per litter was 6.2. The number of stillborn rabbits was recorded as 0.5, corresponding to a stillbirth rate of 6.8% (Table 11). The rates of live births and weaning were 93.2% and 99.7%, respectively. Litter size at birth, number of live births, and number of weaned rabbits increased significantly ($p < 0.001$) with parity rank (Table 12). The live-born rate, stillbirth rate, weaning rate, and number of stillbirths did not vary significantly between groups (Table 12).

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Table 11 Numerical productivity on rabbit farms in Southern Benin

Variable	General (*N*=2162)		Group 1 (*N*=1019)		Group 2 (*N*=657)		Group 3 (*N*=486)		*P*>F
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Litter size at birth	6.7	2.2	6.7^{b}	2.2	6.9^{a}	1.9	6.4^{c}	2.2	***
Born alive	6.2	2.2	6.2^{b}	2.2	6.6^{a}	1.9	5.9^{c}	2.2	***
Born dead	0.5	0.8	0.4^{b}	0.8	0.4^{b}	0.8	0.5^{a}	0.8	*
Litter size at weaning	6.2	2.2	6.2^{b}	2.2	6.5^{a}	1.9	5.8^{c}	2.2	***
Rate of live births (%)[1]	93.2	5.5	93.1	8.1	94.2	9.0	92.5	12.9	NS
Stillbirth rate (%)[1]	6.8	5.5	6.8	8.0	5.8	9.0	8.5	13.7	NS
Weaning rate (%)[1]	99.7	1.3	99.9	1.0	99.6	2.4	99.2	4.4	NS

** : p<0,05; *** : p<0,001; N : Number; NS: Not significant; SD: Standard Deviation;[a, b, c]Means on the same line followed by different letters differ significantly at the 5% threshold;[1]On these lines are percentages and confidence intervals instead of means and Standard Errors and Chi² instead of ANOVA*

Table 12 Influence of parity on various productivity parameters of rabbits from farmers surveyed in Southern Benin

Variable	Parity										RMSE	ANOVA
	1 (*N*=419)	2 (*N*=358)	3 (*N*=324)	4 (*N*=285)	5 (*N*=247)	6 (*N*=190)	7 (*N*=151)	8 (*N*=88)	9 (*N*=55)	10 (*N*=47)		
Litter size at birth	5.6^{f}	6.2^{e}	6.6^{d}	6.9^{cd}	7.3^{bc}	7.44^{b}	7.63^{ab}	7.5^{ab}	7.7^{ab}	8.2^{a}	2.05	***
Born alive	5.1^{f}	5.6^{e}	6.2^{d}	6.5^{cd}	6.8^{bc}	6.9^{ab}	7.2^{a}	7.1^{ab}	7.2^{a}	7.5^{a}	2.04	***
Born dead	0.48	0.52	0.47	0.47	0.48	0.4	0.38	0.29	0.34	0.45	0.86	NS
Litter size at weaning	5^{f}	5.6^{e}	6.1^{d}	6.5^{c}	6.8b^{c}	7^{ab}	7.2^{a}	7.2^{ab}	7.3^{a}	7.7^{a}	2.03	***
Rate of live births (%)[1]	91.4	91.6	92.9	93.3	93.4	94.5	95	96	95.4	94.4	-	NS
Stillbirth rate (%)[1]	8.6	8.4	7	6.7	6.6	5.5	4.9	3.9	4.6	5.6	-	NS
Weaning rate (%)[1]	99.3	99.8	99.6	99.9	99.8	99.5	99.6	99.8	100	99.2	-	NS

**** : p<0,001; NS : Not significant; N : Number; RMSE : Root Mean Squared Error;[a, b, c, d, e, f]Means on the same line followed by different letters differ significantly at the 5% threshold;[1]values are percentages, not mean percentages*

Group 2 had a higher litter size (6.9 heads) than groups 1 (6.7 heads) and 3 (6.4 heads) ($p < 0.001$). The litter size of female rabbits in group 1 was found to be significantly higher ($p < 0.05$) than in group 3. The number of live births and the number of rabbits weaned exhibited a variation according to group, in the same direction as litter size. The number of stillbirths in group 3 was significantly higher than in groups 1 and 2 ($p < 0.05$).

MANAGEMENT OF THE FARM AND DIFFICULTIES ENCOUNTERED

REASON FOR EXITING ANIMALS FROM THE FARM

Table 13 shows that animals left the farm due to diseases, sale, family celebrations, donation, and culling. The majority of farmers (97.5%) took out animals reaching selling age, significantly more frequently ($p < 0.05$) than for culling reason (85%). Additionally, more animals were taken out ($p < 0.05$) for culling than for festive celebration (66.2%). Donations and disease are the least cited reasons for the removal of rabbits.

Table 13 Reasons for animals leaving the farm declared by rabbit breeder farmers surveyed in Southern Benin

Variable	General (*N*=80)		Group 1 (*N*=38)		Group 2 (*N*=26)		Group 3 (*N*=16)		Chi²
	%	CI	%	CI	%	CI	%	CI	
Disease	25^{χ}	9.5	23.7	13.5	26.9	17	25	21.2	NS
Sales	97.5^{α}	3.4	100	0	96.2	7.4	93.8	11.9	NS
Festive celebration	66.3^{δ}	10.4	44.7^{b}	15.8	84.6^{a}	13.9	87.5^{a}	16.2	***
Donation	22.5^{χ}	9.2	23.7	13.5	26.9	17	12.5	16.2	NS
Culling	85^{β}	7.8	84.2	11.6	88.5	12.3	81.3	19.1	NS

**** : p<0.001; N : Number; NS: Not significant; CI: Confidence Interval;[a, b]percentages on the same line followed by the different letters differ significantly at the 5% threshold (for between-group comparison);[α, β, δ, χ]percentages on the same column followed by the different symbols differ significantly at the 5% threshold (for overall percentage)*

The results of the study show that significantly more animals were taken out for festive celebration in groups 2 (84.6%) and 2 (87.5%) than in group 3 (44.7%) ($p < 0.001$).

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DIFFICULTIES ENCOUNTERED

The main difficulty reported was the frequency of disease outbreaks, according to 77.2% of farmers (Table 14). The second most common issue was related to feed, with 68.4% of farmers reporting insufficient availability, high cost, and poor quality. Waste management was a concern for 41.8% of farmers, followed by housing problems at 26.6%. Theft and drinking water supply problems were the least reported issues at 10.1% and 1.3%, respectively. Pathologies and feeding were recognized as the most significant difficulties affecting productivity in farm (Table 14). The cost and quality of feed had a significant impact on productivity. Farmers often found the cost of feed to be too high, which in turn increases the cost of production. Additionally, some farmers have reported that the feed they purchase is of poor quality, resulting in decreased performance and increased rabbit mortality. Pathologies also had a negative effect on productivity, as they can cause mortality and reduce performance.

Table 14 Difficulties encountered by rabbit breeder farmers surveyed in Southern Benin

Variable	General (N=80)		Group 1 (N=38)		Group 2 (N=26)		Group 3 (N=16)		Chi²
	%	CI	%	CI	%	CI	%	CI	
Difficulties encountered									
Diseases	77.2^{α}	9.2	75.7	13.8	84.6	13.9	68.8	22.7	NS
Theft	10.1^{τ}	6.6	10.5	9.8	11.5	12.3	6.3	11.9	NS
Food	68.3^{α}	10.3	52.6^{b}	15.9	80.8^{a}	15.1	81.3^{a}	19.1	*
Habitats	26.6^{δ}	9.7	5.3^{c}	7.1	57.7^{a}	19.0	31.3^{b}	22.7	***
Water	1.4^{λ}	2.5	2.6	5.1	0.0	0.0	0.0	0.0	NS
Waste management	41.8^{β}	10.9	15.8^{b}	11.6	65.4^{a}	18.3	62.5^{a}	23.7	***
Other	10.1^{τ}	6.6	10.5	9.8	3.9	7.4	18.8	19.1	NS
Difficulties affecting productivity in livestock farming									
Food	72.7^{α}	9.9	$52,6^{b}$	15.9	100^{a}	0	75.0^{b}	21.2	***
Diseases	75.3^{α}	9.6	$55,3^{b}$	12.8	92.3^{a}	8.9	93.5^{a}	7.4	**
Technical and organizational	37.7^{β}	10.8	21.6^{b}	13.3	50^{a}	19.2	50^{a}	24.5	*
Other	40.3^{β}	10.9	35.1	15.4	46.2	19.2	37.5	23.7	NS

**: p<0.05; **: p<0.01; ***: p<0.001; N : Number; NS: Not significant; CI: Confidence Interval,* $^{a, b, c}$*percentages on the same line followed by the different letters differ significantly at the 5% threshold (for between-group comparison);* $^{\alpha, \beta, \delta, \tau, \lambda}$*percentages within a class on the same column followed by the different symbols differ significantly at the 5% threshold (for overall percentage)*

Feeding problems were more reported in groups 2 (80.8%) and 3 (81.3%) than in group 1 (52.6%) ($p < 0.05$). Farmers in group 2 were more frequently ($p < 0.05$) confronted with habitat problems than farmers in groups 1 and 3. Farmers in groups 2 and 3 were more frequently confronted with difficulties in managing farm waste ($p < 0.001$). These farmers also had more technical and organizational problems.

DISEASE CONTROL ON RABBIT FARMS IN SOUTHERN BENIN

The results show that 58.7% of farmers had an on-farm prophylaxis plan (Table 15). The prophylaxis plan primarily involved vaccinating the animals against VHD (42.5%) and providing preventive treatment for coccidiosis and scabies (98.7%). Despite the presence of a prophylaxis plan, farmers still had to deal with diseases. The most common pathologies were scabies (70%), gastroenteritis (67%), and VHD (60%) (Table 15). Pathologies were more prevalent during the long rainy season (57.5%). Farmers used modern medicine more frequently ($p < 0.05$) to treat sick animals than traditional medicine or a combination of the both. Animal care mainly involved administering vitamins, deworming, antibiotics, and anticoccidials.

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Table 15 Health monitoring in rabbit farms surveyed in Southern Benin

Variable	General (*N*=80)		Group 1 (*N*=38)		Group 2 (*N*=26)		Group 3 (*N*=16)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Existence of a prophylaxis plan									
Yes	58.7^{α}	10.8	65.8	15.1	50	19.2	56.3	24.3	NS
No	41.3^{β}	10.8	34.2	15.1	50	19.2	43.8	24.3	NS
Pathologies									
Scabies	70^{α}	10.0	60.5^{b}	15.5	88.5^{a}	12.3	62.5^{b}	23.7	*
Gastroenteritis	67^{α}	10.3	57.9	15.7	73.1	17.0	68.8	22.7	NS
VHD	60^{α}	10.7	50	15.9	69.2	17.7	68.8	22.7	NS
Enterotoxemia	1.3^{δ}	2.5	0	0	0	0	6.3	11.9	NS
Oxyurosis	1.3^{δ}	2.5	2.6	5.1	0	0	0	0	NS
Other	38.8^{β}	10.7	39.5	15.5	30.8	17.7	50	24.5	NS
Period of onset of pathologies									
Long rainy season	57.5^{α}	10.8	57.9^{a}	15.7	19.2^{b}	15.1	43.8^{ab}	24.3	**
Short rainy season	17.5^{δ}	8.3	10.5	9.8	23.1	16.2	25.0	21.2	NS
Long dry season	6.3^{γ}	5.3	2.6	5.1	7.7	10.2	12.5	16.2	NS
Short dry season	1.3^{γ}	2.5	2.6	5.1	0	0	0	0	NS
At any time	41.3^{β}	10.8	55.3^{a}	15.8	19.2^{b}	15.1	43.8^{ab}	24.3	*
Treatment mode									
Veterinary medicine	97.5^{α}	3.4	94.7	7.1	100	0	100	0	NS
Traditional medicine	60^{β}	10.7	44.7^{b}	15.8	73.1^{a}	17	75^{a}	21.2	*
Both	57.5^{β}	10.8	39.5^{b}	15.5	73.1^{a}	17	75^{a}	21.2	**
Animal care									
Vaccination	42.5^{β}	10.8	39.5	15.5	42.3	19	50	24.5	NS
Vitamin	97.5^{α}	3.4	100	0	96.2	7.4	93.8	11.9	NS
Deworming	95^{α}	4.8	100	0	96	7.7	93.3	12.6	NS
Antibiotic	98.75^{α}	2.4	100	0	96.2	7.4	100	0	NS
Anticoccidial	98.75^{α}	2.4	100	0	96.2	7.4	100	0	NS

** : p<0.05; ** : p<0.01; N : Number; NS: Not significant; CI: Confidence Interval,* $^{a, b}$*percentages on the same line followed by the different letters differ significantly at the 5% threshold (for between-group comparisons);* $^{\alpha, \beta, \delta, \gamma}$*percentages within classes on the same column followed by the different symbols differ significantly at the 5% threshold (for overall percentages)*

The presence of scabies was more frequently reported ($p < 0.05$) by breeders in group 2 (88.5%) than in groups 1 (60.5%) and 3 (62.5%). Farmers in group 1 (57.9%) declared that they encountered more ($p < 0.05$) diseases in the rainy season than those in group 2 (19.2%). The proportion of farmers who utilized a combination of traditional medicine and veterinary medicine for rabbit treatment in groups 2 (73.1%) and 3 (75%) was significantly higher ($p < 0.05$) than in group 1 (39.5%).

MARKETING

The farms sold males rabbits (93.7%), female rabbits (91.3%), and young rabbits (45%). The proportion of farmers selling males and female reproducers was significantly higher ($p < 0.05$) than that of farmers selling young rabbits. Most of the farms surveyed (81.2%) were able to sell their products easily. Customers included restaurants (72.5%), private individuals (100%), farmers (56.2%), and distributors (15%). For the majority of farmers (82.5%), the optimal time to sell rabbits was during the festive season. Rabbits were sold to customers in two forms: live rabbits (90%) and rabbit carcasses (87.5%). Marketing methods used by all three groups included word-of-mouth and relationships, as well as media. However, the media was used less frequently ($p < 0.05$) than the other two methods. The mean price of a rabbit for consumption was 3,004.7 F CFA.

The categories of animals sold did not vary statistically from one group to another. Farmers in groups 1 and 2 declared that they had no difficulty in selling their rabbits, while those in group 3 reported sales problems (Table 16). Farmers in groups 2 (92.3%) and 3 (100%) sold more during the festive

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season than those in group 1 (31.6%) ($p < 0.05$). The selling prices of the rabbits varied from group to another. Rabbits were more expensive in group 1 (3441.4 F CFA/head) than in groups 2 (2586.5 F CFA/ head) and 3 (2646.9/ head F CFA).

Table 16 Rabbit marketing by rabbit breeder farmers surveyed in Southern Benin

Variable	General (N=80)		Group 1 (N=38)		Group 2 (N=26)		Group 3 (N=16)		Chi²
	%	CI	%	CI	%	CI	%	CI	
Subjects sold									
Reproducer male	93.75^{α}	5.3	94.7	7.1	92.3	10.2	93.8	11.9	NS
Reproducer female	91.25^{α}	6.2	89.5	9.8	92.3	10.2	93.8	11.9	NS
Young rabbits	45^{β}	10.9	39.5	15.5	50.0	19.2	50.0	24.5	NS
Easy product flow									
Yes	81.25^{α}	8.6	100^{a}	0	100^{a}	0	6.3^{b}	11.9	***
No	21.25^{β}	9.0	0^{b}	0	0^{b}	0	100^{a}	0	***
Customers									
Individuals	100^{α}	0	100	0	100	0	100	0	
Restaurant	72.5^{β}	9.8	71.1	14.4	80.8	15.1	62.5	23.7	NS
Distributor	15^{γ}	7.8	13.2	10.7	15.4	13.9	18.8	19.1	NS
Farmer	56.25^{δ}	10.9	47.4	15.9	69.2	17.7	56.3	24.3	NS
Best sales period									
Festive season	82.5^{α}	8.3	68.4^{b}	14.8	92.3^{a}	10.2	100^{a}	0	**
At any time	17.5^{β}	8.3	31.6^{a}	14.8	7.7^{b}	10.2	0^{b}	0	**
Customer services									
Live rabbit sales	90^{α}	6.6	83.8	11.9	96.2	7.4	100	0	NS
Sale of rabbit carcasses	87.5^{α}	7.3	89.2	10.0	88.5	12.3	87.5	16.2	NS
The two services	81.25^{α}	8.6	75.7	13.8	88.5	12.3	87.5	16.2	NS
Other	10^{β}	6.6	8.1	8.8	7.7	10.2	18.8	19.1	NS
Marketing resources									
Word of mouth	91.25^{α}	6.2	92.1	8.6	88.5	12.3	93.8	11.9	NS
Relationship	82.5^{α}	8.3	76.3	13.5	88.5	12.3	87.5	16.2	NS
Advertising (media)	60^{β}	10.7	52.6	15.9	73.1	17.0	56.3	24.3	NS
Other	1.25^{δ}	2.4	0	0	0	0	6.3	11.9	NS

*** : p<0.01; ***: p<0.001; N : Number; NS: Not significant; CI: Confidence Interval,* $^{a, b}$*percentages in the same row followed by the different letters differ significantly at the 5% threshold (for between-group comparison);* $^{\alpha, \beta, \delta, \gamma}$*intra-class percentages in the same column followed by the same letter do not differ significantly at the 5% threshold (for overall percentage)*

Discussion

TYPOLOGY OF RABBIT FARMS

The survey conducted on rabbit farms in southern Benin identified three distinct types of farms, each corresponding to a specific group. Type 1 consists of individuals who have received secondary or university education and who rear rabbits in habitats constructed from wood or cement, in conditions that are satisfactory and in accordance with biosecurity principles. Farmers within this group frequently encounter challenges related to feeding and disease management.To enhance animal productivity, farmers in this group will be provided with technical capacity-building modules aimed at elevating their production levels through the implementation of breeding techniques.This training will empower them to formulate feed formulas and construct habitats that adhere to biosecurity regulations.

Group 2 consists of farmers with no education and at primary school level who have wooden, earthen or tin dwellings with poor biosecurity practices. These farmers will also be able to benefit from

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capacity-building programs with a focus on biosecurity. Although satisfactory, type 3 farmers also need to be strengthened in terms of marketing and sales to ensure better sales of their products. Whatever the type of farming, financial support is needed to increase farmers' production levels. A number of studies have been published on the typology of rabbit farms in Benin. These are the works of Medenou et al. (2020) and Konmey et al. (2023). Each of these studies describes five types of farm. These types differ from those reported in the present study. The observed differences in the types of farms described can be attributed to the variables employed in the classification systems. In addition to the production system, the typology utilised by Medenou et al. (2020) encompasses labour, farm size, investment in cages, and the association with crop production. In contrast, Konmy et al. (2023) concentrate on the diseases encountered, the types of feed and the disease treatment methods, in addition to the rearing system and the size of the farm. In the present study, apart from rearing practices, emphasis was placed on the level of education of the farmers and the difficulties encountered, in order to formulate suggestions for improvement. With regard to the production system, the farmers in our study practise the semi-extensive system reported in the type 2, 3 and 5 farms identified by Konmy et al. (2023). The extensive and semi-claustration systems reported by Konmy et al. (2023) in types 1 and 4 were not recorded in our study because the data were collected only in the south of Benin (rabbit farming area), whereas Konmy et al. (2023) took into account the central and northern regions of the country.

The novelty of our study lies in the fact that we took into account the level of study and the difficulties encountered by the variables in the MCA, which made it possible to establish links between the level of study, the practices and the difficulties.

PROFILE AND PRODUCTION OBJECTIVES OF RABBIT BREEDERS IN SOUTHERN BENIN

Rabbit farming was predominantly carried out by educated men. This observation has also been made in Benin (Yo et al. 2018; Konmy et al. 2023) and in the Democratic Republic of Congo (DRC) (Mutwedu et al. 2015). This strong level of education is advantageous in two respects: firstly, it facilitates the dissemination of technologies and practices that can be used to improve rabbit production, and secondly, it contributes to the professionalisation of the sector (Yo et al. 2018).

The primary method of building up the livestock was through purchasing, as the cost of buying animals is not high and is affordable for the surveyed individuals who are mainly educated and have other income-generating activities such as trade, crafts, government jobs, and livestock farming. Similar observations were made in rabbits farming in Benin (Konmy et al. 2023). Rabbits are reared for sale by farmers, although some production is for own consumption, indicating that rabbit rearing is a source of income for the majority of households surveyed, as reported by Yo et al. (2018).

HABITATS AND BIOSECURITY IN RABBITS' FARMS

The construction materials of the housing described in this study have already been reported in rabbit farming in Benin (Kpodekon et al. 2018; Yo et al. 2018) and Senegal (Fall et al. 2019). The walls of the buildings are made of bricks, the roof of tin and the floor of cement. Kpodekon et al. (2018) recommend the use of local materials such as dirt, rattan, racks, bamboo, wood, straw, palm or coconut branches

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to construct economically viable buildings. Using these materials, brick walls could be replaced with dirt, rattan, wood, racks and bamboo, and the roof could be made of palm or coconut branches and straw. Group 2 farmers use less hard housing than Group 1 and 3 farmers, which could be explained by the lack of financial resources to build modern rabbit housing by Group 2 farmers. As a result of these financial problems, some farmers in Benin do not even have housing for their rabbits, and the animals are kept in rabbit cages installed either next to their huts, under a simple shelter, or in the backyard of their houses (Yo et al. 2018; Konmy et al. 2023). The farmers used metal cages to house the animals, indicating an improved farming practice. These types of cages were reported in semi-improved farms in Benin by Yo et al. (2018). In contrast to this finding, rabbit farmers in Kaolack, Senegal, used wooden cages (Fall et al. 2019). In Benin, this type of cage is found in traditional farms (Yo et al. 2018). Hygiene is generally acceptable in all farms, as the farmers are educated and practice semi-intensive farming.

The animal waste is commonly used to fertilize soil or sold. This practice helps to limit its impact on the environment by avoiding odours for neighbours. However, caution should be exercised when selling waste, particularly in group 2, as buyers may inadvertently transport and deposit pathogens in another farm. It is not advisable to dispose of animal carcasses in open pits, as this can lead to the spread of pathogens that may have caused the animal's death.

FEEDING PRACTICES

Farmers used commercial feed in pellet form because it is available. In addition, farmers used an improved system with a high level of investment, which forces them to pay close attention to animal nutrition, as an imbalance in nutrition has a negative impact on animal growth (Darmohray et al. 2017; de Blas and Wiseman 2020). Farmers mainly used granulated feed as it is easily consumed by animals, unlike floury feed which can cause respiratory diseases (Kpodekon et al. 2009, 2018; Djago et al. 2010).

The majority of farmers in Benin offered forage that they collect from surrounding bushes in their rabbit feed because rabbits consume it well (de Blas and Wiseman 2020). However, farmers must be cautious about where they harvest the forages and how they treat them, as they may contain pathogens harmful to the animals. There are only 13 types of forages identified, which is relatively low compared to the list established by Djago et al. (2010). The limited use of forages is attributed to the challenges of accessing them in urban areas like Cotonou and Abomey-Calavi. Livestock farmers have to travel long distances to obtain forages (Yo et al. 2018). Most farmers use *Moringa oleifera* due to its availability and accessibility. In addition, several studies have been conducted on this plant in rabbits, yielding encouraging results for animal growth and health status (Dahouda et al. 2013; Honvou et al. 2017; Olounladé et al. 2021). Other forages that are not commonly used or not used at all by farmers, such as *Panicum maximum C1*, *Aeschynomene histrix*, *Stylosenthèse hamata*, *Arachis pintoï*, *Brachiaria ruzinzis*, *Elaeis guineensis*, *Ipomoea aquatica*, *Azolla sp*, *Puerara phaseoloides* and *Tridax procumbens*, have also been successfully tested on the zootechnical performance of rabbits (Mmereole et al. 2011; Akoutey and Kpodekon 2012; Akoutey et al. 2012; Obinne et al. 2013; Adande et al. 2017; Sana et al. 2020). Breeders can incorporate these plants among the plants frequently used in rabbit feed. In addition to these food resources, rabbit breeders often use by-products such as cereal and agricultural oilseed bran in rabbit feed (Mutwedu et al. 2015; Tchibozo et al. 2017; Alabi et al.

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2018). The respondents did not mention these resources because the study was conducted in an area where crop production activities are less developed and, above all, because the farmers have adopted commercial feed and concentrates.

In groups 2 and 3, the majority of farmers provide well water to their rabbits, which is in contrast to the practice observed in Senegal where tap water is given to the animals (Fall et al. 2019). The main use of well water in Benin is due to its availability in the study area and a lack of awareness regarding its quality. Farmers should exercise caution when using this source, as it may contain microbial germs such as *Escherichia coli* and *Salmonella* (Kpodekon et al. 2018).

REPRODUCTION MANAGEMENT

Breeders select male rabbits based on conformation, growth performance, health status, and kinship. These criteria are recommended for rabbit breeders in tropical environments (Djago et al. 2010). In addition to these criteria, Djago et al. (2010) suggested to use the parental performance. The absence of data recording on farms may be the reason for the lack of use of performance data in farm. The criteria associated with parental performance, particularly numerical productivity, should be included in the list of criteria for reproducers selection by farmers. Currently, the criteria used mainly focus on weight performance (Gidenne 2015) and do not take into account numerical productivity. Selected males are used to mate females at 5.2 months of age. This age falls within the range of 5 to 6 months suggested by Kpodekon et al. (2018), but is lower than the 6 to 7 months reported in the DRC and Senegal (Mutwedu et al. 2015; Fall et al. 2019).

The same criteria used for selecting males are also used to select females, as suggested by Kpodekon et al. (2018). However, maternal qualities have been ignored by breeders in this regard. The selected females are mated at the age of 4.69 months and this age is in line with the age of 4 to 5 months recommended by Kpodekon et al. (2018). It is also aligned with the reproducing age of rabbits in farms in Benin and Senegal (Yo et al. 2018; Youssao et al. 2018; Fall et al. 2019). The weaning age was approximately 33 days which is in line with the recommended 30 to 35 days for weaning of young rabbits (Gidenne 2015; Kpodekon et al. 2018). The same observation was made for the weaning age in Côte d'Ivoire (Kimse et al. 2017). However, the weaning age was lower than the 54-day age reported in the DRC (Mutwedu et al. 2015). The weaning age in the DRC is too long and causes economic losses for farmers (Kpodekon et al. 2018).

The criteria for culling breeding stock were loss of libido, locomotion problems, reduced litter size, high mortality of bunnies at birth and parity rank. These reasons for culling are also reported by Gidenne (2015) in rabbit farms. Culling criteria are classified into two groups: sanitary culls and culls for infertility (Gidenne 2015).

FARM PRODUCTIVITY

The litter size at birth was 6.7 ± 0.05 rabbits. Similar litter sizes ranging from 6.8 to 7.4 bunnies have been reported on rabbit farms in Benin, Congo, and DRC (Akouango et al. 2014; Mutwedu et al. 2015; Youssao et al. 2018). Lower litter sizes ranging from 5.78 to 6 rabbits have been reported in Benin and Côte d'Ivoire (Aholou et al. 2017; Kimse et al. 2017; Koutinhouin et al. 2017). The litter size recorded

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in this study is smaller than the litters of 8 to 8.5 bunnies reported in Nigeria, Congo, and Senegal (Akouango et al. 2014; Fall et al. 2019; Onuoha et al. 2020). Variability in litter size is linked to genetic type. The genetic type of the rabbits reared by breeders was mostly unknown, which limits the analysis of results. Including plants such as *Moringa oleifera*, *Cissus populnea*, *Synedrella nodiflora*, *Sphenostylis stenocarpa*, *and Moringa stenopetala* in the feed has been shown to improve litter size (Odeyinka et al. 2016; Aholou et al. 2017; Koutinhouin et al. 2017). Additionally, litter size is higher when mating occurs after weaning rather than during lactation (Akouango et al. 2014). The low birth mortality rate indicates satisfactory hygiene in the nest boxes. The high weaning rate recorded also applies to zootechnical performance, particularly litter size, which has been previously demonstrated to increase with parity rank by Gidenne (2015) and Akpo et al. (2008).

FARM MANAGEMENT AND DIFFICULTIES ENCOUNTERED

Animals were taken out mainly for sale, culling, and festive celebrations, as previously reported in Benin and Burkina-Faso (Kindo 2017; Yo et al. 2018). Rabbits are frequently taken out during end-of-year celebrations, Easter, and Ramadan, especially in groups 1 and 2 (Kindo 2017; Yo et al. 2018). In some cases, breeders, particularly those in group 1, may sell their animals during ceremonies due to the high frequency of such events in large cities like Abomey-Calavi and Cotonou. Additionally, group 1 farmers may opt to sell their rabbits when they fall ill, as the cost of treatment may exceed the value of the animal. This is often the most profitable option, as noted by Djago et al. (2010) and Kpodekon et al. (2018), provided that the illness does not pose a risk to human health. The farmers in group 3 produced for sale but do not have a sales strategy, which may explain the problems in selling their rabbits.

Rabbit farming in southern Benin faced major difficulties in terms of pathologies and feeding. These difficulties are also reported in previous studies on rabbit farming in Burkina-Faso, Senegal and Congo (Akouango et al. 2014; Kindo 2017; Fall et al. 2019). Feeding problems arise due to the rabbit's monogastric digestive system, which requires a significant portion of its feed to be provided by humans. The existence of these problems on farms suggests a lack of professionalism among breeders. Improved organization on their part could help to reduce these problems. The presence of pathological difficulties indicates that the current biosecurity measures are not effective in preventing disease.

The most common diseases found on rabbit farms in Benin were scabies, diarrhea, and VHD. These diseases have been previously reported by Akpo et al. (2012) and Kpodekon et al. (2015). VHD, in particular, has become a major concern for breeders in recent years as it has caused significant losses in the herd (Yo et al. 2018). Pathologies are less frequently reported in group 3 due to the higher level of education of the breeders, which enables them to implement better biosecurity measures on their farms. Pathologies typically occur during the rainy season when the presence of water creates a favorable environment for pathogen proliferation.

MARKETING

The rabbits produced are in high demand for two reasons. Firstly, the meat is of good quality (Djago et al. 2010; Kpodekon et al. 2018; Yo et al. 2018; Tougan et al. 2019). However, this quality can quickly

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deteriorate due to unsatisfactory handling of rabbit carcasses on farms (Adogoni et al. 2021). The second reason is that VHD has significantly reduced rabbit populations, resulting in a shortage of supply. The customer base includes restaurants, individuals, breeders, and distributors, as previously noted in works by Kpodekon et al. (2018), Yo et al. (2018), and Adanguidi (2020). The selling price of rabbit's ranges from 2586 F CFA to 3441 F CFA per head, which is consistent with the price range of 2500 to 3000 F CFA reported by Yo et al. (2018) for breeding rabbits in Benin. The reason for the similarity in price between breeding stock and the mentioned price is that breeders sell live animals to other breeders.

Conclusion and recommendations

The study examined the breeding practices of rabbit farms and identified three distinct groups of breeders. Groups 1 and 3, which consisted of university graduates, had more satisfactory breeding conditions compared to group 2. The latter group had marked shortcomings in hygiene and biosecurity, which led to pathologies affecting productivity and early culling of animals. Furthermore, the organization of livestock farmers was poor, which prevented them from meeting their feed costs. These challenges, particularly diseases, can significantly reduce the herd, resulting in the need for breeders to sell their rabbits quickly. Based on these findings, it is recommended that training or awareness-raising sessions be provided to farmers in group 1 regarding the importance of strengthening biosecurity measures on their farms. Additionally, they should receive training in the technical and economic management of their farms. Finally, it may be beneficial for individuals in group 3 to consider developing their marketing and commercialization skills, as this could potentially lead to an improvement in the sales of their products.

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Author contributions Daouda ASSOUMA, Ignace Ogoudanan DOTCHE and Issaka YOUSSAO ABDOU KARIM conceived the study design. Daouda ASSOUMA, Ignace Ogoudanan DOTCHE and Vanessa Nissirine KOUNDE collected the data wrote the manuscript. Ignace Ogoudanan DOTCHE, Mahamadou DAHOUDA and Issaka YOUSSAO ABDOU KARIM analyzed the data collected. Jean-Luc HORNICK, Guy Apollinaire MENSAH and Jean-Paul DEHOUX corrected the manuscript. All authors read and approved the final manuscript.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Declarations

Ethical approval This is an observational study. The Research Ethics Committee of our Department has confirmed that no ethical approval is required.

Conflict of interest The authors declare that there are no conflicts of interest.

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