



Genetic Improvement of Rabbits and It's Limitations in Southern Benin

**Daouda Assouma ^a, Ignace Ogoudanan Dotché ^{a*},
Samiratou Tairou Yacoubou ^{a,b}, Yao Akpo ^b,
Goussanou Judicael ^a, Jean-Luc Hornick ^c,
Issaka Youssao Abdou Karim ^a and Jean-Paul Dehoux ^d**

^a *Laboratory of Animal Biotechnology and Meat Technology University of Abomey-Calavi (UAC), Polytechnic School of Abomey-Calavi (EPAC), 01BP 2009, Benin.*

^b *Faculty of Agronomic Science, University of Parakou, Benin.*

^c *Department of Veterinary Management in Animal Resources, Tropical Veterinary Institute, Faculty of Veterinary Medicine, FARAH Unit, University of Liège, Vallée 2, Avenue de Cureghem, B-4000 Liège, Belgium.*

^d *Experimental Surgery Unit, Faculty of Medicine, Université Catholique de Louvain, 55/70, Avenue Hippocrate, 1200, Brussels, Belgium.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors DA, IOD and IYAK conceived the study design. Authors DA, IOD, GJ and STY collected the data and wrote the manuscript. Authors IOD, YA and IYAK analyzed the data collected. Authors J-LH and J-PD corrected the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/jeai/2025/v47i43357>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/133075>

Original Research Article

Received: 24/01/2025

Accepted: 26/03/2025

Published: 09/04/2025

*Corresponding author: E-mail: dotcheign@gmail.com;

ABSTRACT

Background: The rabbit farming industry is characterized by the predominance of local rabbit breeds. Significant endeavours have been undertaken to enhance the genetic quality of these breeds through selection programs, yielding substantial advancements in the area that have subsequently been disseminated to various rabbit farming communities.

Aims: The study aims to identify the constraints and limits to the genetic improvement of rabbits in Benin.

Methodology: The study was conducted with 80 rabbit breeders in the Departments of Ouémé, Mono, Couffo, Atlantique and Littoral in southern Benin during January to July 2022. The farmers were questioned about their identity, the methods they employed in farming, the genetic improvement techniques they utilized on their farms, and the constraints associated with these techniques. The collected data were analyzed with SAS software (SAS Institute Inc., Cary, NC, USA) and R Version 4.0.2. The MCA function of R's Facto MineR library was used for multiple correspondence analysis (MCA). For quantitative variables, an analysis of variance was performed using the PROC GLM procedure in SAS, and the only variation factor considered in the model was the effect of the breeding group. The Fisher test was used to determine the significance of this effect, and comparisons between group means were made in pairs using the Student's t test.

Results: The first group consists of farmers who use selection as a genetic improvement method. Group 2 consists of farmers who use both selection and crossbreeding, and group 3 consists of farmers who use crossbreeding. The problems affecting the genetic improvement of breeds were difficulties in obtaining pure breeds, as well as financial, technical and sanitary difficulties. The low availability of pure breeds was mentioned more often in group 1 than in group 2. Health problems were mentioned more often in group 2 than in group 1. Even if farmers declared that they were making progress, the lack of performance recording, the lack of performance monitoring and the non-synchronisation of efforts make improvements less perceptible on the ground.

Conclusion: To remedy these shortcomings, it would be necessary to encourage the emergence of selection breeding to supply pure-bred animals to breeders and to seek solutions to the problems faced by farmers.

Keywords: Rabbits; selection; crossbreeding; exotic breeds; Benin.

1. INTRODUCTION

Rabbit farming is one of the sustainable and profitable agricultural practices due to the higher fecundity, efficient feed conversion, and the ability of rabbits to adapt to a variety of environments as well as the lower initial investment and a small production area required to breed rabbits on the large scale (Anongo et al., 2023; Goswami et al., 2025). In Benin, rabbit farming is a practice that is widely engaged in, and its meat is widely consumed by the population (Yo et al., 2018). The high level of participation by the population in this farming activity is associated with the relatively short production cycle for rabbits (Fontanesi, 2021). The consumption of this meat by the population is associated with the quality of the rabbit meat (Siddiqui et al., 2023). It can be reasonably proposed that rabbit farming may assist the country in attaining self-sufficiency in animal protein.

The breeding of short-cycle species such as rabbits was promoted to intensify meat production in order to reduce or even eliminate the massive imports of meat into Benin. This led to a significant development of the rabbit industry, particularly with the dissemination of innovative technologies by the Centre Cunicole de Recherche et d'Information (CeCURI, UAC) (Kpodekon & Coudert, 1993). These CeCURI innovations are supported by the work of other actors in the sector. In general, improvement work has focused on increasing numerical and weight productivity through health monitoring, feeding and breeding practices (Kpodekon et al., 2000, 2004; Koutinhoun et al., 2009; Akpo et al., 2012; Konmy et al., 2023). These various works have contributed to improvements in farm production, though the results have not always aligned with the efforts made. After solving the technical problems, the low yields in the sector are linked to the genetic types of animals reared (Alabi et al., 2022). Nowadays, genomic-assisted selection (GAS) and precision nutrition (PN)

approaches are used to enhance the production and farming potential of rabbits as the demand for rabbit meat and sustainable raw materials is growing worldwide. GAS, particularly genomic selection (GS), Marker-assisted Selection (MAS), Genome-wide Association Studies (GWAS), Genomic prediction models, and genotyping and phenotyping, have been widely adopted in animal breeding programs due to its potential to improve selection accuracy, minimize phenotyping, reduce cycle time, and increase genetic gains (Wongnaa et al., 2023; Benedek et al., 2023).

In Benin, the rabbit farming industry is characterised by the predominance of local rabbit breeds (Alabi et al., 2022). Significant endeavours have been undertaken to enhance the genetic quality of these breeds through selection programs, yielding substantial advancements in the area that have subsequently been disseminated to various rabbit farming communities (Akpo et al., 2008). Other studies have addressed crossbreeding with imported semen of exotic strains from developed countries (Dotché et al., 2018). The supervision of all of the aforementioned work was conducted by CeCURI. However, due to its success, CeCURI is no longer in a position to satisfy the increasing demand for new farmers, in terms of providing reproducers and assistance to farmers. This has resulted in farmers themselves selecting breeder stock on ordinary farms based on criteria that are not always objective, and in the uncontrolled introduction of animals of foreign breeds. Furthermore, inbreeding occurs on farms, which has a detrimental impact on animal performance (Yo et al., 2018). In light of this, it is imperative to provide farmers with the necessary support to effectively manage their animal resources. The objective of this study is to delineate the typology of rabbit farms based on genetic improvement methods, thereby identifying the challenges and constraints associated with breed improvement on farms in southern Benin. The results of this study will facilitate the more structured development of genetic improvement strategies for common rabbits in Benin.

2. MATERIALS AND METHODS

2.1 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 on the challenges and limits of improving the genetics of rabbits was conducted in five regions of southern Benin. These departments were Ouémé, Mono, Couffo, Atlantique, and Littoral (Fig. 1). The area in question is located within the sub-equatorial region (except Couffo), and is characterised by a bimodal rainfall pattern, with two distinct rainy seasons and two dry seasons. Temperatures range from 25 to 30°C, with precipitation levels ranging from 900 to 1500 mm at the isohypse. Couffo department, which is 2,404 km², has a Sudano-Guinean climate, with one rainy season and one dry season. The area gets between 800 and 1,200 mm of rain each year. The average temperature is between 25 and 28°C.

2.2 Protocol

The study was conducted through direct interviews with farmers. The lack of a comprehensive register of rabbit farmers in the region prompted the decision to employ the snowball sampling technique (Parker, Scott & Geddes, 2019). The initial list of farmers to be surveyed was obtained from the databases of the Agence Territoriale de Développement Agricole Pôle 7. As a result, other farmers were identified and surveyed. A total of 80 individuals were interviewed. The farmers were questioned about their identity, the methods they employed in farming, the genetic improvement techniques they utilized on their farms, and the constraints associated with these techniques. Data were collected using a survey form. The survey sheet included information on farmer identification, herd size and structure, genetic improvement techniques, constraints to genetic improvement, difficulties, origin of animals used, breeds reared, and consequences of inbreeding. The questions were semi-closed.

2.3 Statistical Analysis

The collected data were analyzed with SAS software (SAS Institute Inc., Cary, NC, USA) and R Version 4.0.2. The MCA function of R's FactoMineR library was used for multiple correspondence analysis (MCA) (Kassambara, 2017). Variables considered in the correspondence analysis were breeds reared, genetic improvement methods, crossbreeding types, selection types, selection criteria, animal

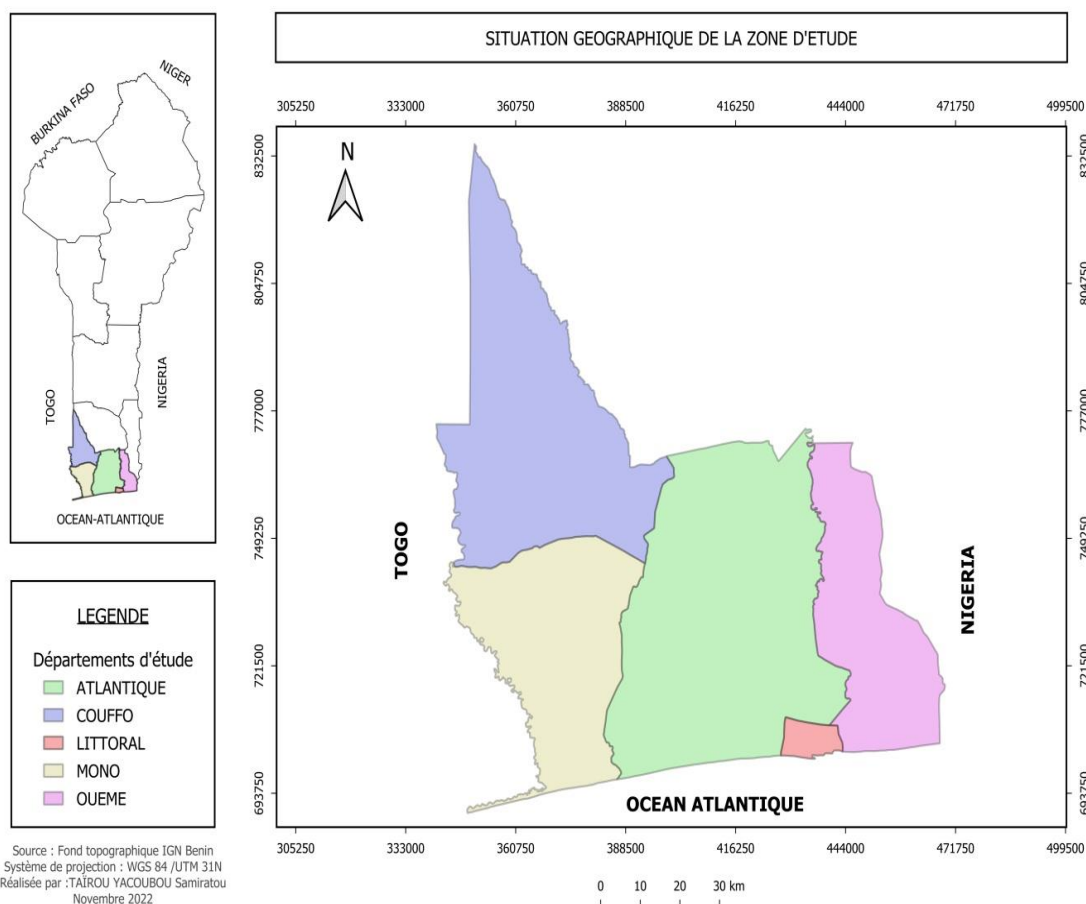


Fig. 1. Geographical location of the departments in the study area

genetic improvement objectives and breed genetic improvement constraints. The MCA was followed by a hierarchical ascending classification using R's HCPC function, based on the characteristics of the most significant MCA components. Three groups of farmers were then identified. The frequencies of the characteristics of these groups were compared by Chi² test using the SAS PROC FREQ procedure (SAS, 2013) for categorical variables. Relative frequencies between groups were compared in pairs using the two-tailed Z-test. For each relative frequency, a 95% confidence interval (CI) was calculated using the formula:

$CI = 1,96 \sqrt{([P(1-P)]/N)}$, where P is the relative frequency and N is the sample size.

For quantitative variables, an analysis of variance was performed using the PROC GLM procedure in SAS, and the only variation factor considered in the model was the effect of the breeding group. The Fisher test was used to determine the significance of this effect, and

comparisons between group means were made in pairs using the Student's t test.

3. RESULTS

3.1 Socio-Professional Characteristics of Different Groups of Farmers

The first three axes were employed for interpretation of the results of the multiple correspondence analysis (MCA). The contribution to the total inertia of the three factorial axes was 49.4% (25.5% for the first axis, 17.6% for the second, and 6.3% for the third). Each axis represents a group of farmers. The results of the factorial analysis are illustrated in Fig. 2.

The first group, "Breeding with selection," comprises 45 farmers. These farmers utilize selection exclusively as a genetic improvement method. They predominantly employ the local breed and select on pedigree.

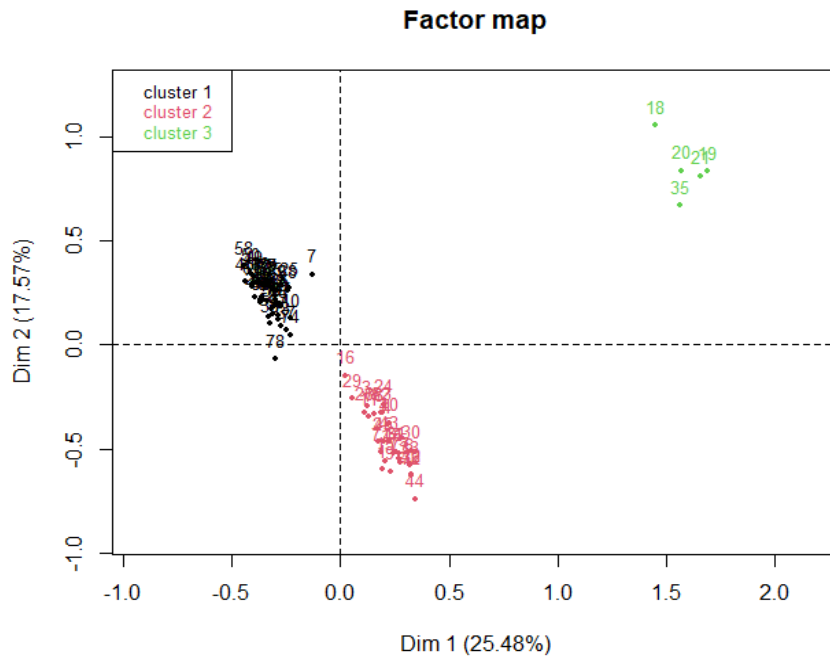


Fig. 2. Typology of rabbit farms in southern Benin

Group 2, designated as "Breeding with Selection and Crossbreeding," consists of 30 farmers. These farmers engage in the processes of selection and crossbreeding on their respective farms. They rear local rabbits and foreign breeds, primarily Hyla. They frequently practice crossbreeding, followed by selection on pedigree, sometimes including collateral.

Group 3, designated "Breeding with crossbreeding," consists of five farmers. These farmers are considered novices, with approximately five years of professional experience. Their focus is exclusively on crossbreeding. Their livestock comprises both local and foreign breeds. The predominant crossbreeding method employed is absorption crossbreeding.

The socio-professional characteristics of the farmers remain consistent across the various groups (Table 1). The majority of the rabbit's farmers were men (91.3%) and Christian (92.5%). The sociolinguistic groups encountered are diverse, with the Fon group representing the largest proportion (46.3%). The majority of farmers in southern Benin (76.3%) have less than a decade's experience in the field of rabbit breeding. The group of farmers with between 10 and 20 years of experience represents 17.5% of the total number surveyed. The remaining 6.3% of farmers have more than 20 years of

experience. The majority of farmers have obtained a university degree, representing 62.5% of the total sample (Table 1). The predominant activity of rabbit farmers in southern Benin is breeding, accounting for 41.3% of the total. The second most prevalent activity is civil service, with a percentage of 21.3. Agriculture occupies the third position with a percentage of 10%. Other activities, including handicrafts, trade, and apprenticeships, account for 27.5% of the total.

3.2 Rabbit Breeding Management

The most prevalent breed was the local rabbit, representing 95% of the total population. This was followed by Hyla, which constituted 37% of the total, and other foreign breeds, including "Fauve de Bourgogne" and crossbreeds. The local breed is the result of a process of anarchic crossbreeding between exotic breeds. The proportion of Group 1 farms (100%) engaged in the breeding of the local breed was significantly higher than that of pure crossbreeding farms (Group 3). Conversely, rabbits of foreign breeds were observed to be more prevalent on group 2 and 3 farms than on group 1 farms. The majority of respondents (65%) indicated that they house rabbits in sheds, while the remainder (35%) utilized other structures for this purpose. The type of housing does not vary significantly between the different groups (Table 2). Inside the

buildings and sheds, the animals were housed in cages made of wire mesh, metal and wood. Metal cages (80%) and wire mesh (73.8%) were the most commonly used.

The animals were fed a diet comprising 97.5% commercial feed, 66.3% forage, and 12.5% a mixture of raw materials. Notably, none of the farmers in Group 3 utilized forage as a dietary

component for their rabbits, as illustrated in Table 3. The raw materials utilized in the formulation of the feed are oilseed cake (13.8%), cereal bran (10%), oilseed bran (6.2%), industrial spent grains (3.7%), and other components, including lysine and cereals. The fodder for the animals is composed of oil palm leaves, moringa leaves, basil, potatoes, and other ingredients, including banana and pigeon peas.

Table 1. Profile of surveyed farms

Variable	General (N=80)	
	%	Confidence interval
Religion		
Islam	6.3 ^b	5.3
Christianity	92.5 ^a	5.8
Animist	1.2 ^b	2.4
Years of experience		
< 10	76.3 ^a	9.3
10 and 20	17.5 ^b	8.3
> 20	6.2 ^c	5.3
Study level		
Out of school	6.2 ^c	5.3
Primary	5 ^c	4.8
Secondary	26.3 ^b	9.6
University	62.5 ^a	10.6
Marital status		
Married	63.8 ^a	10.5
Single	35 ^b	10.5
Widow	1.25 ^c	2.4
Farmer's main activity		
Breeding	41.2 ^a	10.8
Agriculture	10 ^c	6.6
Civil servant	21.3 ^b	8.9
Other	27.5 ^b	9.8

NS: Not significant; ^{a,b,c}: Intra-class percentages in the same column followed by different letters differ at the 5% threshold

Table 2. Animal housing and breeds reared

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		Chi ²
	%	CI	%	CI	%	CI	%	CI	
Rabbit habitat									
Building	35	10.4	28.9	13.2	36.7	17.2	80	35.1	NS
Hangar	65	10.4	71.1	13.2	63.3	17.2	20	35.1	NS
Rabbit cage									
Wood	21.3	8.9	22.2	12.1	23.3	15.1	0	0	NS
Iron	80	8.8	82.2	11.2	73.3	15.8	100	0	NS
Grids	73.8	9.6	60 ^b	14.3	90 ^a	10.7	100 ^a	0	*
Breeds									
Local	95	4.8	100 ^a	0	90 ^{ab}	10.7	80 ^b	35.1	*
Hyla	37	10.6	4.4 ^b	6.0	80 ^a	14.3	80 ^a	35.1	***
Other	27.5	9.8	2.2 ^b	4.3	60 ^a	17.5	60 ^a	42.9	***

CI: Confidence interval; NS: Not significant; *: $p < 0.05$; ***: $p < 0.001$; ^{a,b,c}: percentages in the same line followed by different letters differ significantly at the 5% threshold

Table 3. Rabbits feeding

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		Chi ² T
	%	CI	%	CI	%	CI	%	CI	
Commercial feed	97.5	3.4	95.6	6.0	100	0	100	0	NS
Raw material mix	12.5	7.2	11.1	9.2	16.7	13.3	0	0	NS
Forages	66.3	10.4	75.6 ^a	12.6	63.3 ^a	17.2	0 ^b	0	**

CI: Confidence interval; NS: Not significant; **: $p < 0.01$; ^{a,b,c}: percentages of the same line followed by different letters differ significantly at the 5% threshold

Table 4. Livestock structure

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		ANOVA
	Average	SE	Average	SE	Average	SE	Average	SE	
Reproducers males									
Local	1.8	0.4	2.6	0.4	0.9	0.5	1	1.3	NS
Improved	1.1	0.4	0.1 ^b	0.4	2.2 ^a	0.5	3.6 ^a	1.3	**
Cross	0.9	0.3	0.1 ^b	0.3	2.2 ^a	0.4	1.6 ^a	0.2	***
Reproducers females									
Local	10.9	3.4	16.8 ^a	3.4	3.2 ^b	4.2	4 ^{ab}	10.2	*
Improved	2.8	1.2	0.3 ^c	1.2	4.3 ^b	1.5	17.4 ^a	3.6	***
Cross	9.1	4.4	0.9 ^b	4.4	21.5 ^a	5.4	8 ^{ab}	13.3	***
Under-mother bunnies									
Local	19.3	7.44	31.4	3.37	3.37	9.11	6	22.3	NS
Improved	8.1	5.13	0.1 ^b	5.13	15.83 ^{ab}	6.28	33.8 ^a	15.39	*
Cross	13.9	3.89	1.8 ^b	3.89	33.27 ^a	4.77	6 ^b	11.68	***
Fattening young males rabbits									
Local	13.2	4.6	18.4	6.4	6.4	5.6	6	13.7	NS
Improved	6.3	5.3	1.4	5.3	12	6.4	17	15.8	NS
Cross	18.6	5.9	0.3	5.9	47.9	7.3	8.2	17.9	NS
Fattening female rabbits									
Local	0.8	0.6	0.4	0.6	1.53	0.7	0	1.7	NS
Improved	0.4	0.5	0.1	0.5	1.0	0.6	0	1.6	NS
Cross	1.8	1.1	0.4	1.1	2.8	1.3	8	3.2	NS
Total herd	109.1	18.4	74.9 ^b	18.4	158.5 ^a	22.5	120.6 ^{ab}	55.2	*

*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; NS: Not significant; ^{a, b}: Averages on the same line followed by different letters do not differ significantly at the 5% threshold.

The mean number of rabbits on the farms visited was 109.13 (Table 4). The herd size was found to be significantly larger ($p < 0.05$) in group 2 (158.5 head) compared to group 1 (74.9 head). The farms had three genetic types of animals: local, exotic, and crossbred. The average number of males used for mating was 1.84 for the local breed, 1.1 for the improved breed, and 0.96 for the crossbred. The number of improved and crossbred males was higher ($p < 0.01$) in groups 2 and 3 than in group 1. The farms had an average of 10.9 local breed females, 2.8 improved breed females, and 9.1 crossbred females. A statistically significant difference was observed in the number of female reproducers between groups 2 and 3 ($p < 0.05$). Group 3 exhibited a higher mean number of improved

breed females compared to group 1. Furthermore, Group 2 exhibited a higher number of crossbred breed females compared to Group 1. The mean number of offspring per dam was 19.3 for the local breed, 8.1 for the improved breed, and 13.9 for the crossbred breed. In groups 2 and 3, improved and crossbred bunnies were more significant. Rabbits for fattening averaged 13.1 for local breeds, 6.3 for improved breeds and 18.6 for crossbreeds.

3.3 Genetic Improvement Methods of Rabbits in Southern Benin

The farmers who participated in the survey reported that they primarily engaged in genetic improvement through selection. Crossbreeding

was employed by 43.75% of the farmers surveyed. Farmers in the first group primarily employed selection as a strategy for genetic enhancement, while those in the third group predominantly utilized cross-breeding. Group 2 farms utilize a combination of both methods for genetic enhancement in livestock production. Of the two groups that utilize crossbreeding, Group 3 farms employ absorption crossbreeding with greater frequency ($p < 0.001$) compared to Group 2 farms. Conversely, crossbreeding was more prevalent in group 2 than in group 3. These crossbreeding efforts were primarily aimed at enhancing three key aspects of rabbit production: the growth rate of the local rabbit (97.1%), the breed's reproductive performance (88.6%), and disease resistance in foreign breeds (25.7%).

The predominant selection method employed was pedigree selection. In addition to this method, some farms in Group 2 employ collateral selection (Table 5). A combination of criteria is employed to identify the most optimal breeding stock. The most frequently employed criteria were as follows: litter size (87.5%), maternal aptitude (86.25%), growth rate of fattening animals (62.5%), and male mating capacity (58.7%). Group 2 farms demonstrated a higher utilization of weight at fixed age and carcass yield in comparison to Group 1 farms when selecting optimal breeding stock. The most frequently selected animals were females

(100%). The implementation of these genetic improvement initiatives has been reported to result in tangible progress and enhanced economic profitability for rabbit farmers in southern Benin, as evidenced by survey results (63.8% and 97.5%, respectively).

3.4 Constraints and Limits of Rabbit Genetic Improvement

The problems cited by farmers as affecting the genetic improvement of the local breed were breed problems, financial problems, technical problems, and health problems (Table 6). The proportion of farmers reporting breed (75%) and health (73.8%) problems was significantly higher than that of farmers reporting financial (33.7%) and technical (7.5%) problems. Group 1 exhibited a higher frequency of mentions concerning Breed problems when compared to Group 2. Conversely, health problems were more ($p < 0.05$) frequently cited in group 2 (96.7%) than in group 1 (57.8%).

Breed problems were associated with a lack of purebred suppliers. Technical problems are associated with a deficiency in the adeptness of selection techniques. Health problems are associated with pathologies that affect performance and result in the elimination of selected animals (Table 6).

Table 5. Genetic improvement methods

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		Chi ²
	%	CI	%	CI	%	CI	%	CI	
Genetic improvement method									
Crossbreeding	43.7	10.9	0 ^b	0	100 ^a	0	100 ^a	0	***
Selection	93.8	0	100 ^a	0	100 ^a	0	0 ^b	0	***
Crossbreeding methods									
Metissage and creation of composite strains	88.6	10.5	-	-	96.7 ^a	6.4	20 ^b	35.1	**
Absorption	14.3	11.6	-	-	0 ^b	0	100 ^a	0	***
Improvement and industrial	48.6	16.6	-	-	53.3	17.8	20	35.1	NS
Crossbreeding objectives									
Growth improvement	97.1	5.5	-	-	96.7	6.4	100	0	NS
Improved reproductive performance	88.6	10.54	-	-	86.7	12.2	100	0	NS
Improved resistance	25.7	14.48	-	-	20	14.3	60	42.9	NS
Selection methods used									
Ancestry selection	100	0	100 ^a	0	100 ^a	0	0 ^b	0	***
Collateral selection	1.2	2.4	0	0	3.3	6.4	0	0	NS
None	6.2	5.3	0 ^b	0	0 ^b	0	100 ^a	0	***
Selection criteria									
Litter size	87.5	7.2	93.3 ^a	7.3	93.3 ^a	8.9	0 ^b	0	***

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		Chi ²
	%	CI	%	CI	%	CI	%	CI	
Number of live rabbits at weaning	20	8.8	20	11.7	23.3	15.1	0	0	NS
Weight of rabbits at weaning	30	10	22.2	12.1	46.7	17.8	0	0	NS
Growth	62.5	10.6	60	14.3	76.7	15.1	0	0	NS
Rabbit weight at a fixed age	27.5	9.8	17.8 ^b	11.2	46.7 ^a	17.8	0 ^{ab}	0	*
Carcass yield	27.5	9.8	6.7 ^b	7.3	63.3 ^a	17.2	0 ^b	0	***
Male robustness	58.8	10.8	60 ^a	14.1	66.7 ^a	16.9	0 ^b	0	**
Maternal instinct	86.2	7.5	88.9 ^a	9.18	96.7 ^a	6.4	0 ^b	0	***
None	6.2	5.3	0 ^b	0	0 ^b	0	100 ^a	0	***
Selection purpose									
Best reproducers	3.8	4.2	4.4	6	33	6.4	0	0	NS
Better growth	71.2	9.9	75.6 ^a	12.6	76.7 ^a	15.1	0 ^b	0	**
Better resistance	3.8	4.2	4.4	6	3.3	6.4	0	0	NS
Good carcass	8.8	6.2	4.4	6	16.7	13.3	0	0	NS
None	12.5	5.3	11.1 ^b	9.2	0 ^b	0	100 ^a	0	***

CI: Confidence interval; NS: Not significant; *: p<0.05; **: p<0.01; ***: p<0.001; a,b,c: percentages in the same row followed by different letters differ significantly at the 5% threshold.

Table 6. Constraints to genetic improvement

Variable	General (N=80)		Group 1 (N=45)		Group 2 (N=30)		Group 3 (N=5)		Chi ²
	%	CI	%	CI	%	CI	%	CI	
Constraints and limits of genetic improvement									
Breed problems	75	10.3	84.4 ^a	12.1	63.3 ^b	17.5	60 ^{ab}	35	*
Financial problems	33.8	10.4	42.2	14.4	23.3	15.1	20	35.1	NS
Technical problems	7.5	5.8	13.3	9.9	0	0	0	0	NS
Health problems	73.8	9.6	57.8 ^b	14.4	96.7 ^a	6.4	80 ^{ab}	35.1	**
Frequent diseases									
Scabies	71.2	9.9	75.6	12.6	63.3	17.2	8	35.1	NS
Intestinal disorders	31.2	10.2	22.2	12.1	43.3	17.7	40	42.9	NS
Abortive disease	5	4.8	2.2	4.3	10	10.7	0	0	NS
External parasitosis	3.8	4.2	6.7	7.3	0	0	0	0	NS
Coccidiosis	45	10.9	33.3 ^b	13.8	63.3 ^a	17.2	40 ^{ab}	42.9	*
Viral Hemorrhagic Diarrhea	8.8	6.2	8.9	8.3	10	10.7	0	0	NS
Period of onset of disease									
Rainy season	17.5	8.3	13.3	9.9	23.3	15.1	20	35.1	NS
Dry season	1.2	2.4	2.2	4.3	0	0	0	0	NS
Any time of year	81.2	8.5	84.4	12.1	76.7	15.1	80	35.1	NS

CI: Confidence interval; NS: Not significant; *: p<0.05; **: p<0.01; a,b,c: percentages in the same row followed by different letters differ significantly at the 5% threshold.

Scabies was identified as the most prevalent disease in the surveyed rabbit farms (Table 6). Following coccidiosis and intestinal disorders, it was the most prevalent disease. Abortive diseases, viral hemorrhagic diarrhea (VHD), and ectoparasites (without scabies) were observed less frequently. The proportions of farmers reporting these diseases did not vary from one group to another, with the exception of coccidiosis, which was reported more frequently in group 2. These diseases can appear at any

time of the year, and farmers have developed coping mechanisms, including the use of veterinary products, to manage them.

3.5 Origin of Reproducers and Risk of Inbreeding

The lack of purebred suppliers resulted in the farmers surveyed (96.3%) procuring their reproducers from farms (96.1%) and intermediaries (5.2%). A significant majority of

Table 7. Origin of breeders and consequences of inbreeding on animal performance

Variable	General		Group 1		Group 2		Group 3		Chi ²
	%	CI	%	CI	%	CI	%	CI	
Purchase of breeding stock									
Yes	96.2	4.2	93.3	7.3	100	0	100	0	NS
No	3.8	4.2	6.7	7.3	0	0	0	0	NS
Place of purchase of reproducers									
Farm	96.1	4.3	92.8	7.8	100	0	100	0	NS
Other	5.2	4.9	7.2	7.8	3.3	6.4	0	0	NS
Males and females on the same farm									
Yes	13.3	7.7	15	11.1	13.3	12.2	0	0	NS
No	86.7	7.7	85	11.1	86.7	12.2	100	0	NS
Purchase from a farmer who bought from you									
Yes	21.8	9.2	25.6	13	20	14.3	0	0	NS
No	78.2	9.2	74.4	13	80	14.3	100	0	NS
Consequences of inbreeding									
Mortality at birth	30	10	31.1 ^b	13.5	20 ^b	14.3	80 ^a	35.1	*
Mortality between birth and weaning	22.5	9.2	22.2	12.1	16.7	13.3	60	42.9	NS
Weak bunnies at birth	22.5	9.2	17.8	11.2	23.3	15.1	60	42.9	NS
Slow growth	18.8	8.5	15.6	10.6	16.7	13.3	60	42.9	NS
Reduced range size	16.2	8.1	6.7 ^b	7.3	20 ^b	14.3	80 ^a	35.1	***
Very small live births	1.2	2.4	0 ^b	0	0 ^b	0	20 ^a	35.1	***
High abortion rate	5	4.8	6.7	7.3	0	0	20	35.1	NS
Other	8.8	6.2	11.1	9.2	6.7	8.9	0	0	NS

CI: Confidence interval; NS: Not significant; *: $p < 0.05$; ***: $p < 0.001$; ^{a,b,c}: percentages in the same row followed by different letters differ significantly at the 5% threshold.

these farmers did not procure males and females from the same farm (Table 7). A negligible proportion of farmers purchased from farms with which they had previously engaged in the sale of reproducers. Concerning the matter of inbreeding, farmers reported a multitude of unfavorable consequences on animal performance. The most significant of these was high mortality at birth with a percentage of 30%, followed by mortality between birth and weaning (22.5%), fragility of young rabbits at birth (22.5%), slow growth (18.8%), reduced litter size (16.2%), high abortion rate (5%), fewer live births (1.2%), and other consequences such as morphological malformations in the offspring. The proportion of farmers with high birth mortality in Group 3 was significantly higher ($p < 0.05$) than in the other two groups. Notably, farmers in group 3 were the only ones to report a decline in the number of live-born rabbits, concurrent with an increase in the abortion rate.

4. DISCUSSION

The rabbit habitat consists primarily of sheds and buildings constructed of concrete, as reported in works on rabbit farming in Benin (Konmy et al., 2023) and Senegal (Fall et al., 2019). The cages

are predominantly composed of wire mesh and iron, as reported by Konmy et al. (2023) in rabbit farms in Benin. The preponderance of metal cages indicates that the farms adhere to a semi-intensive management system, as this type of cage has been frequently documented in semi-intensive farms in Benin (Alabi et al., 2022). It is important to note that rabbit rearing does not occur in a free-roaming environment and necessitates a minimal investment in housing, feed, health monitoring, and follow-up management.

The rabbit breeds reared on farms in southern Benin consist of local and crossbred rabbits. The presence of these breeds, particularly local rabbits, has been extensively documented on farms in southern Benin (Yo et al., 2018; Alabi et al., 2022). The provision of animal feed was facilitated by commercial feed, forage, and a mixture of raw materials, as reported by Medenou et al. (2020) and Konmy et al. (2023). While the utilization of forages is strongly recommended in rabbit farming to avoid digestive disorders (Kpodekon et al., 2018), farmers must take precautions to ensure that these forages do not encourage diseases to enter the farm.

Farmers employ two well-established methods to enhance animal performance: crossbreeding and selection. These techniques have been utilized for a considerable period, as evidenced by the extensive research conducted on the subject (Khalil & Al-Saef, 2008; Dotché et al., 2018). Selection is the most frequently employed method by farmers, primarily due to its accessibility. This accessibility is attributable to the fact that selection is carried out within the same breed, eliminating the need to import an improver breed, which is associated with procedural and adaptation difficulties. The selection criteria employed by farmers, such as litter size, maternal aptitude, growth rate, and mating aptitude of the male, are readily quantifiable in the parents. The selection of collaterals was reported in Group 2, as farmers in this group predominantly measure carcass quality criteria on collaterals. The overarching objective of selection is to enhance growth performance, which substantiates the selection of growth rate as the primary selection criterion. This approach aligns with the principles of genetic improvement, which necessitates a clear relationship between the criterion and the selection objective (Fontanesi, 2021).

In contrast to Group 1 farmers, farmers in Groups 2 and 3 utilize crossbreeding due to their objective of accelerating the improvement of performance (Dotché et al., 2018). The pursuit of performance enhancement is not the sole rationale for crossbreeding; the development of disease-resistant products is also a key objective. The expectation is that these objectives will be achieved through the complementarity between the two breeds (Fontanesi, 2021). Consequently, crossbreds are expected to benefit from the superior performance of their exotic parent and the disease resistance of their local breed parent.

The genetic enhancement of rabbit breeds is confronted with various challenges, including breed-related problems, financial constraints, technical challenges, and health concerns. The dearth of pure breeds, as previously documented by Yo et al. (2018), is a salient concern. Indeed, as a result of chaotic and diverse intra- and inter-strain crossbreeding, the most dominant strains in Benin are the mixed breeds (Kpodekon et al., 2018). The absence of pure breeds poses significant challenges to the pursuit of genetic enhancement, as farmers frequently lack

comprehensive knowledge about the genotype and performance of the animals utilized. In the absence of pertinent information, the establishment of an effective cross-breeding and selection scheme would be challenging. Indeed, the knowledge of pedigrees and performances facilitates the utilization of selection techniques, such as Blup (Viana et al., 2022). The existence of breed-related problems can be attributed to the absence of specialist selection farms. However, Group 1 farmers have asserted their specialization in selection. However, these farms do not meet the criteria of a traditional selection farm. This is due to the fact that they lack pure breeds and reliable information on the animals utilized, including their genetic value. Furthermore, animal performance is assessed subjectively, which complicates the evaluation of genetic progress.

Farmers have established selection criteria; however, these criteria are not always logical. Firstly, the same criteria are often used to select all the animals. This approach does not result in substantial enhancement of performance. Ideally, male and female lines should be available, with criteria applied to each line (Pascual Amorós et al., 2008; Boucher et al., 2021). Consequently, criteria such as prolificacy (live rabbits/litter), rabbit growth, female longevity, and number of udders are frequently applied to the maternal line, while criteria such as average daily gain, carcass yield, carcass fatness, feed efficiency, and digestive health are applied to the paternal line (Khalil & Al-Saef, 2008; Blasco et al., 2018; Boucher et al., 2021). A number of these criteria, frequently employed in the context of rabbit selection, are not applicable to our farms due to the absence of performance data. Secondly, there is an inconsistency between the selection objectives and selection criteria. For instance, the majority of farmers (97%) use litter size as a selection criterion, while only a small percentage (4%) focus on enhancing reproductive performance as a selection objective. Similarly, some farmers aim to improve animal resistance, even though there is no criterion associated with this objective among the selection criteria. It is these shortcomings that justify the technical problems mentioned by farmers. It is important to note that there are other technical difficulties that farmers have also identified. One such problem is inbreeding, which has been shown to have negative consequences on animal performance (Nagy et al., 2013; Ragab et al., 2015; Curik et al., 2020; Piles et al., 2023). It has been observed that farmers are implementing

measures to circumvent this issue. These measures include the practice of refraining from the purchase of animals of the same sex within the same farm, as well as the avoidance of acquiring reproducers from former customers. However, the absence of a comprehensive traceability system on the farm renders it difficult for farmers to ascertain the absence of a common ancestor among the animals.

From a financial perspective, the majority of farmers interviewed reported challenges in procuring superior reproducers, largely due to their high costs. These reproducers were sold to the highest bidders. In addition to the purchase of reproducers, farmers face escalating expenditures on animal feed (Alabi et al., 2022; Konmy et al., 2023).

In the health sector, pathologies emerge and impact select reproducers, thereby distorting anticipated outcomes. The most prevalent pathologies include scabies, coccidiosis, diarrhea, and viral hemorrhagic diarrhea (VHD). These diseases are caused by insufficient sanitary prophylaxis. Some of these diseases have already been reported on rabbit farms in Benin (Medenou et al., 2020; Konmy et al., 2023). These diseases occur throughout the year. Notably, diseases such as VHD have the capacity to impede the progress achieved by farmers by eliminating reproducers. Selection can contribute to the enhancement of animal resistance to these diseases (Gunia et al., 2015, 2018), as selection for disease resistance has previously demonstrated its efficacy (Gunia et al., 2015, 2018). To achieve this objective, farmers must incorporate disease resistance criteria into their selection criteria. The identification of disease-resistance traits is predicated on the observation of clinical signs, including abscesses, coryza, diarrhea, external signs of infection, and leanness. In certain instances, the autopsy of animals is employed to discern lesions in various organs (Shrestha et al., 2018). Farmers can utilize records of observable disease symptoms, identified at a specific age, as a tool for sorting. The objective is to retain only healthy rabbits as reproductive animals to ensure the renewal of the herd.

A notable absence in the field is a collective organization in genetic improvement work, which remains at the herd level and, under these conditions, cannot contribute significantly to breed improvement.

5. CONCLUSION

The study revealed that three distinct types of farms were identified, contingent on the breeds reared and the genetic improvement methods employed. The three groups are as follows: breeding practising selection only (group 1), breeding practicing selection and crossbreeding (group 2), and breeding practising crossbreeding only (group 3). The constraints imposed on production genetic improvement are associated with technical, financial, breed management and health difficulties. Farmers utilizing crossbreeding (groups 2 and 3) are more prone to encounter health challenges, while those employing selection (group 1) face challenges in breed management. Financial constraints have been shown to limit access to improved strains and to determine the choice of method (selection or crossbreeding) to be used. Technical challenges, frequently associated with the presence of criteria that are not aligned with the intended objectives and the implementation of the selected method, are significant in determining the outcomes achieved. For genetics to make an effective contribution to improving rabbit production in Benin, solutions must be found to the following problems. One potential solution for farmers is the establishment of a rabbit genetic improvement cooperative, with the aim of coordinating efforts to achieve greater gains. Concurrently, sustained research initiatives by academic institutions and research organizations are imperative to ascertain the genotypes of breeds raised and the performance of these animals. Furthermore, these institutions could assume a more active role in the genetic enhancement of farms by establishing a national rabbit genetic improvement program. Organizations and authorities could support these actions by financing the work and organizing capacity-building training courses to address technical challenges and biosecurity on farms.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT

Written informed consent was obtained from all farmers interviewed in the study.

ACKNOWLEDGEMENT

The authors thank the "Académie de Recherche et d'Enseignement Supérieur (ARES) of Belgium for its support to the realization of this work through Research and Development Project (PRD) entitled " Amélioration de la compétitivité marchande des lapins de race commune élevée au Sud Bénin par l'optimisation des performances de production et de reproduction et l'implication des différents acteurs de la filière".

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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