



Bioeconomic evaluation of production losses from inbreeding depression in rabbit breeding

I Losses from the negative influence of inbreeding depression on the reproductive qualities of female rabbits (does)

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Abstract: The main goal of this article is to conduct simulation on rabbit farms with an intensive and extensive reproductive cycle, which will allow to monitor and analyze the inbreeding depression. Setting up that goal, the article will also take into consideration the bio-economics status and how it affects the production losses from inbreeding depression on the reproductive qualities of female rabbits.

Keywords: Bio-economics, inbreeding depression, rabbits

Introduction

One of the elements of the wide range of tasks and activities included in the definition of the term bioeconomy is "science-based efficient and sustainable use of biological resources for the production of food, medicine, consumables, and other biologically based materials necessary for the existence and development of humanity in combination with the protection of the environment through, the development of economically justified strategies and projects to achieve these goals" (Dibios and Gomez San Juan 2016). Scientific research and deepening of knowledge about the mechanisms and processes at the genetic, molecular and genomic level, prevention of the loss of biological diversity and creation of highly effective biotechnologies are important for achieving all this. One of the main directions of the world economy related to the production of food and food products is animal breeding, where the preservation, improvement and use of genetic resources (breeds, lines and hybrids) is essential for the economic efficiency of the production activity. In this regard, in recent years, in the field of animal breeding science, complex studies have been conducted on a bio-economic basis, where the biological analysis of the productive traits are refracted through the prism of economic efficiency or inefficiency. In particular, such bio-economic studies are also carried

out in the rabbit farming system, where the production of rabbit meat as a dietary food for humans meets the requirements for complete protein nutrition. On the other hand, along with the search for the positive effects of selection, nutrition, breeding technology, it is necessary to study, control and eliminate negative biological phenomena that adversely affect the productivity of farm animals. Such is the example of the phenomenon of inbreeding depression, which occurs as a result of inbreeding. The genetic nature of this phenomenon is primarily explained by bringing many alleles of certain genes into a homozygous state. In doing so, some of the effects of dominance and overdominance are lost and conditions are created for the appearance of recessive unwanted genes. The negative effect is expressed in the manifestation of morphological, biochemical and physiological disorders in the offspring (Leroy 2014, Tanchev 2006, Tanchev et al., 2016). It has been established that high levels of inbreeding negatively affect primarily the signs related to reproductive abilities, vitality and adaptability of animals to changing environmental conditions.

In addition, growth qualities, feed utilization and productivity in general deteriorate (Hinkovski et al., 1975, Erokhin et al., 1985, Falconer 1985, Venev and Stoykov 2002, Boykovski 2003). Of interest in this regard are the studies on the harmful influence of inbreeding depression in the domestic rabbit (*Oryctolagus cuniculus*), which, apart from being a convenient object for biological research, is also one of the types of farm animals. Studies by a number of authors show that increasing the degree of inbreeding in rabbit populations leads to a decrease in live births and weaned rabbits as well as the fertility of mother does in general (Chai 1969, Poujardiel and Toure 1980, Toro et al., 1988, Park et al. al., 1990, Ferraz et al., 1992, Bielanski et al., 1993, Tanchev 2006, Nagy et al., 2011, Ragap et al., 2015, Palka et al., 2016, Tanchev et al., 2018). On the other hand, an increase in the degree of inbreeding (Fx) leads to a decrease in genetic diversity in populations and the occurrence of adverse population effects. This is of particular importance for small populations, where inbreeding leads to a pronounced erosion of genetic diversity. The adaptability and ability of organisms to respond sustainably to changing environmental conditions is impaired, which is sometimes the reason for the extinction of entire populations and breeds of animals (Lacy et al., 1996, Rege and Gipson 2003, Martin – Burriel et al., 2011, Taberlet et al., 2011, Tanchev 2016, Leroy 2017). Along with the studies on the biological essence and the negative influence of inbreeding depression on the productive signs in farm animals and in particular in the domestic rabbit, the question arises as to what is the impact of this phenomenon on the production and economic efficiency of the rabbit breeding activity. In general, although few in number, similar bioeconomic studies in the field of rabbit breeding are carried out, but all of them are mainly aimed at comparative analysis of the economic efficiency of different breeding technologies, different feeding systems, etc. (Mobolaji - Bukola et al., 2002, Krupova et al., 2020, Otero – Watitua et al., 2020).

Bearing in mind the detailed scientific information presented above, with the present study we set ourselves the goal, based on experimental data, to make a bio-economic analysis and evaluation of production losses from inbreeding depression on the reproductive qualities of female rabbits placed in the conditions of two different reproductive systems.

Materials and methods

A total of 110 sexually mature individuals aged 7 to 30 months were examined to study the reproductive qualities of female rabbits. Their distribution by groups is as follows:



- Heterogeneous crosses - $F_x = 0 \rightarrow 8$ pcs.; $F_x = 0.125 \rightarrow 7$ pcs.; $F_x = 0.25 \rightarrow 8$ pcs.; $F_x = 0.375 \rightarrow 8$ pcs.; $F_x = 0.5 \rightarrow 8$ pcs.; $F_x = 0.625 \rightarrow 8$ pcs.;

- Homogeneous purebred (Californian) - $F_x = 0 \rightarrow 8$ pcs.; $F_x = 0.125 \rightarrow 8$ pcs.; $F_x = 0.25 \rightarrow 8$ pcs.; $F_x = 0.375 \rightarrow 8$ pcs.; $F_x = 0.5 \rightarrow 8$ pcs.; $F_x = 0.625 \rightarrow 7$ pcs.

All animals in the groups by origin (breeding) and in subgroups by step of inbreeding were relatively equal in age, and the differences in most cases did not exceed 4 months.

Three to five litters were counted and tracked for each mother doe. The number of reported young rabbits in the heterogeneous groups was 189 and in the homogeneous groups also 189, or a total of 378 bunnies were reported. The number of controlled rabbits in the heterogeneous groups was 1339, and in the homogeneous groups 1501, or a total of 2840 rabbits.

The traits were controlled: total number of rabbits born, number of live births and stillbirths, number on day 21; number of rabbits weaned on day 41. In some of the groups, the number of inseminations until fertilization was also controlled.

All animals were placed under identical feeding and breeding conditions.

Data from the conducted experiments were processed by one-, two- and three-factor analysis of variance. In processing, we used additive fixed-effects models. Depending on the number of traits analysed, we used ANOVA (when analysing a single trait) or MANOVA (when analysing more than one trait simultaneously) models. We considered a statistically significant influence of the studied factor at a critical level of $p < 0.05$.

Multiple comparisons between groups were performed using the LSD test. We adopted $p < 0.05$ as the critical level for statistically significant differences.

All statistical treatments were performed using the statistical package STATISTICA of the StatSoft. Inc. company.

Results and discussion

The results of the influence of the factors, the degree of inbreeding and breed relation on the reproductive qualities of the mother does are shown in Table 1. The analysis shows that both studied factors exert a statistically significant influence on all the investigated traits. Tracking the average values of reproductive indicators (Table 2) shows the dynamics of changes depending on inbreeding levels and breed specificity. The comparative analysis of the arithmetic means clearly shows that in both breed groups the increase in the degree of inbreeding leads to a decrease in the mean values characterizing the reproductive qualities of the rabbits. In both purebred rabbits and heterogenous crosses, this is particularly well expressed after an inbred level of $F_x = 0.250$. The results of the multiple mathematical comparisons between groups and subgroups (Table 3, Table 4, Table 5, Table 6) show that there are 33% to 47% statistically significant differences, confirming the negative influence of high degrees of inbreeding on the reproductive qualities of female animals.

In most of the other cases of multiple comparisons, despite the absence of statistical significance, the tendency for negative effects of inbreeding on the studied traits is also well expressed. Similar to our results are the results of other authors. For example, Chai (1969) reported that when F_x was increased by 10%, live births decreased by 0.7 on average.



Poujardiel and Toure (1980) found that increasing inbreeding in female rabbits by 10% resulted in a significant reduction in births, live births and weanlings. Jarwiska's (1988) study led to the conclusion that an increase in the degree of inbreeding (F_x) led to a decrease in the ovulation rate and fertility of the rabbits studied. Deterioration of reproductive abilities due to inbreeding depression in different breeds of rabbits was also reported by Toro et al. (1988), Park et al. (1990), Ferraz et al. (1992), Bielanski et al. (1993), Farghaly (2000), Tanchev et al. (2016). Our genetic analysis based on experimental data as well as the studies of the cited authors show that the increase in the degree of inbreeding leads to inbreeding depression, which negatively affects the reproductive qualities of rabbits - a product of inbreeding. It is known, however, that the state of the reproductive process in livestock farms and in particular in meat rabbit farming is a major factor determining to a large extent the economic efficiency of the production activity (Marinov et al. 2009). In this sense, based on the results of the genetic analysis, we directed our attention to the economic evaluation of the production reproductive losses from inbreeding depression in two virtual farms with a capacity of 100 female rabbits.

The results of the organized simulation analysis in these farms with two systems of reproduction - intensive and extensive (according to methods of Ivanov and Grigorov 2002, Ivanov et al. 2004) with different degrees of inbreeding, are presented below. In the case of the intensive reproductive cycle, one mother is expected to produce seven litters per year, and in the extensive cycle - four litters. Another important economic indicator that we included as a final element of the mathematical model is the number of rabbits weaned on the 41st day for each individual inbred level. The product of the number of mother does, the number of rabbits and the average number of weaned rabbits obtained from the conducted experiments represents the total number of weaned rabbits for the respective farm according to the adopted reproduction system for one economic year. Analysis of the results shows that increasing the levels of inbreeding on both virtual farms leads to a decrease in the total number of rabbits weaned. This is less pronounced at the inbreeding levels $F_x = 0.125$ and $F_x = 0.250$, while at the following inbreeding levels the reduction in the number of weaned rabbits expressed in percentages as a result of inbreeding depression strongly increases. A comparison of the two virtual farms shows that the extensive cycle farm shows a higher percentage of weanling losses at day 41.

On the one hand, the reason for this is the lower average initial fertility, and on the other hand, the smaller number of births of the non-consolidated starting population, which we called a conditionally heterogeneous group. In principle, in purebred California rabbit breeding farms (homogenous) control of reproductive qualities is carried out and high degrees of inbreeding are not allowed. In contrast, in small amateur and production farms very often the breeds are not kept in a pure state, spontaneous crossing is carried out without control of reproductive and other productive qualities. This spontaneity is often accompanied by close inbreeding that continues over a number of successive generations. In this case, both a certain part of the selected valuable characters and the effect of the crossing are lost.

The conducted simulation analysis on rabbit farms with an intensive and extensive reproductive cycle shows that inbreeding depression has a strong negative impact on the reproductive qualities of mother does and, in particular, on the number of rabbits weaned from them. In principle, the total number of weaned rabbits obtained in a given rabbit farm with a relevant reproductive system for one economic year is an important partial element involved in the formation of the overall economic efficiency of the production process. In this sense, based on the results of our study, we can conclude that the reduction in the number of



weaned rabbits as a result of inbreeding depression can lead to significant economic losses. Without completely denying the application of inbreeding in rabbit breeding and, in general, in animal breeding, sometimes used as a breeding method to consolidate and maintain certain valuable qualities, we can categorically state that increasing the level of inbreeding to and above degree $F_x = 0.250$ presents a large risk of inbreeding depression. Its harmful impact on the reproductive process in the rabbit farm leads to large production losses, which reflect negatively on the final economic efficiency.

Conclusion

The conducted simulation analysis on rabbit farms with an intensive and extensive reproductive cycle shows that inbreeding depression has a strong negative impact on the reproductive qualities of mother does and, in particular, on the number of rabbits weaned from them.

A reduction in the number of rabbits weaned as a result of inbreeding depression can lead to significant economic losses.

Increasing the level of inbreeding to and above the degree of $F_x = 0.250$ carries a great danger of inbreeding depression. Its harmful impact on the reproductive process in the rabbit farm leads to large production losses, which reflect negatively on the final economic efficiency.

Acknowledgements

*We would like to express our greatest appreciation to **prof. Svetlin Tanchev** - for his priceless efforts, knowledge and dedication. He was the most important leader in awakening our diligence, bringing us to the deepest scientific sources, and encouraging all of us to continue pursuing our professional and personal goals.*

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Table 1. Individual and combined influence of the level of inbreeding and origin factors on the studied reproductive features in mother does.

INDICATORS	SOURCES OF INFLUENCE					
	Level of inbreeding		Origin		Both	
	F	p	F	p	F	p
Number of young born per litter	24.16	< 0.0001	34.24	< 0.0001	0.99	0.42
Number of liveborn	27.02	< 0.0001	48.33	< 0.0001	0.84	0.52
Number of stillborn	2.59	0.26	2.04	0.15	1.21	0.30
Number of live young on the 21st day	27.03	< 0.0001	54.62	< 0.0001	0.92	0.47
Number of weaned on the 41-st day	33.75	< 0.0001	49.91	< 0.0001	1.98	0.08



Table 2. Average values of the surveyed reproductive indicators in does by groups depending on the degree of inbreeding and origin.

Source of influence		Indicators (Average $\pm$ SE)				
Inbreeding level	Origin	Number of young born per litter	Number of liveborn	Number of stillborn	Number of live young on the 21st day	Number of weaned on the 41-st day
F_x=0	Homogeneous	8.65 $\pm$ 0.22	8.09 $\pm$ 0.16	0.56 $\pm$ 0.12	7.83 $\pm$ 0.13	7.31 $\pm$ 0.14
	Heterogeneous	7.67 $\pm$ 0.23	7.29 $\pm$ 0.20	0.38 $\pm$ 0.08	7.11 $\pm$ 0.16	6.85 $\pm$ 0.16
F_x=0.125	Homogeneous	8.42 $\pm$ 0.16	7.91 $\pm$ 0.16	0.47 $\pm$ 0.10	7.51 $\pm$ 0.16	6.8 $\pm$ 0.11
	Heterogeneous	7.6 $\pm$ 0.17	7.04 $\pm$ 0.15	0.56 $\pm$ 0.11	7 $\pm$ 0.15	6.6 $\pm$ 0.16
F_x=0.250	Homogeneous	7.90 $\pm$ 0.20	7.33 $\pm$ 0.19	0.57 $\pm$ 0.10	7.21 $\pm$ 0.17	6.75 $\pm$ 0.15
	Heterogeneous	7.36 $\pm$ 0.23	6.36 $\pm$ 0.29	1 $\pm$ 0.27	6.12 $\pm$ 0.27	5.69 $\pm$ 0.25
F_x=0.375	Homogeneous	7.38 $\pm$ 0.16	6.67 $\pm$ 0.13	0.61 $\pm$ 0.10	6.61 $\pm$ 0.13	6.22 $\pm$ 0.12
	Heterogeneous	6.93 $\pm$ 0.13	6.09 $\pm$ 0.14	0.83 $\pm$ 0.14	5.90 $\pm$ 0.13	5.38 $\pm$ 0.13
F_x=0.500	Homogeneous	7.06 $\pm$ 0.11	6.53 $\pm$ 0.09	0.53 $\pm$ 0.11	6.4 $\pm$ 0.10	5.86 $\pm$ 0.10
	Heterogeneous	6.73 $\pm$ 0.14	6.08 $\pm$ 0.11	0.64 $\pm$ 0.11	5.88 $\pm$ 0.11	5.20 $\pm$ 0.13
F_x=0.625	Homogeneous	6.85 $\pm$ 0.11	6.46 $\pm$ 0.10	0.39 $\pm$ 0.09	6.39 $\pm$ 0.10	5.89 $\pm$ 0.11
	Heterogeneous	6.38 $\pm$ 0.11	6 $\pm$ 0.13	0.38 $\pm$ 0.10	5.80 $\pm$ 0.14	5.38 $\pm$ 0.13



Table 3. Results of multiple comparisons by the number of young born per litter (values of statistical significance level - (p)).

Inbreeding level											
Fx=0		Fx=0.125		Fx=0.250		Fx=0.375		Fx=0.500		Fx=0.625	
Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero
8.7± 0.2	7.7± 0.2	8.4± 0.2	7.6± 0.2	7.9±0.2	7.4± 0.2	7.4± 0.2	6.9± 0.1	7.1± 0.1	6.7± 0.1	6.9± 0.1	6.4± 0.1
1	2	3	4	5	6	7	8	9	10	11	12
1	<0.001	0.3493	<0.001	0.0026	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2		0.0017	0.7703	0.3385	0.1983	0.2415	0.0028	0.0147	0.0001	0.0013	<0.001
3			0.0015	0.0317	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4				0.2413	0.3700	0.4257	0.0132	0.0481	0.0010	0.0068	<0.001
5					0.0263	0.0363	0.0001	0.0008	<0.001	<0.001	<0.001
6						0.9248	0.0857	0.2367	0.0100	0.0479	0.0001
7							0.0743	0.2086	0.0085	0.0414	<0.001
8								0.6064	0.4175	0.7624	0.0303
9									0.1837	0.4226	0.0078
10										0.6310	0.1589
11											0.0703

Table 3. Results of multiple comparisons by the number of young liveborn per litter (values of statistical significance level - (p)).

Inbreeding level											
Fx=0		Fx=0.125		Fx=0.250		Fx=0.375		Fx=0.500		Fx=0.625	
Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero
8.1± 0.2	7.3± 0.2	7.9± 0.2	7.0± 0.2	7.3±0.2	6.4± 0.3	6.7± 0.1	6.1± 0.1	6.5± 0.1	6.1± 0.1	6.5± 0.1	6± 0.1
1	2	3	4	5	6	7	8	9	10	11	12
1	<0.001	0.4443	<0.001	0.0015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2		0.0075	0.3148	0.8671	<0.001	0.0090	<0.001	0.0016	<0.001	0.0007	<0.001
3			<0.001	0.0128	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4				0.2490	0.0081	0.1601	<0.001	0.0516	<0.001	0.0290	<0.001
5					<0.001	0.0060	<0.001	0.0010	<0.001	<0.001	<0.001
6						0.1913	0.2662	0.4831	0.2403	0.6829	0.1301
7							0.0170	0.5575	0.0130	0.3941	0.0050
8								0.0761	0.9714	0.1421	0.6911
9									0.0645	0.7841	0.0300
10										0.1249	0.7110
11											0.0639



Table 5. Results of multiple comparisons by the number of live young on the 21st day in the litter (values of statistical significance level - (p)).

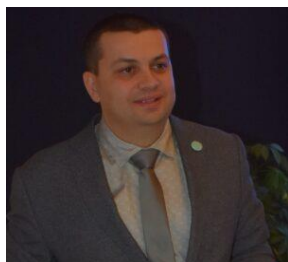
Inbreeding level											
Fx=0		Fx=0.125		Fx=0.250		Fx=0.375		Fx=0.500		Fx=0.625	
Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero
7.8± 0.2	7.1± 0.2	7.5± 0.2	7± 0.2	7.2± 0.2	6.1± 0.3	6.6± 0.1	5.90± 0.1	6.4± 0.1	5.9± 0.1	6.4± 0.1	5.8± 0.1
1	2	3	4	5	6	7	8	9	10	11	12
1	0.0013	0.1454	0.0006	0.0057	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2		0.0685	0.6207	0.6683	<0.001	0.0240	<0.001	0.0016	<0.001	0.0010	<0.001
3			0.0300	0.1680	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4				0.3754	0.0002	0.1110	<0.001	0.0140	<0.001	0.0140	<0.001
5					<0.001	0.0080	<0.001	<0.001	<0.001	<0.001	<0.001
6						0.0290	0.3343	0.2210	0.2790	0.2416	0.1636
7							0.0020	0.3571	0.0010	0.3498	<0.001
8								0.0320	0.9258	0.0370	0.6728
9									0.0220	0.9760	0.0100
10										0.0270	0.7348
11											0.0100

Table 6. Results of multiple comparisons by the number of weanlings on the 41st day in the litter (values of the statistical significance level - (p)).

Inbreeding level											
Fx=0		Fx=0.125		Fx=0.250		Fx=0.375		Fx=0.500		Fx=0.625	
Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero	Homo	Hetero
7.3± 0.2	6.9± 0.2	6.8± 0.1	6.6± 0.2	6.8± 0.2	5.7± 0.3	6.2± 0.1	5.4± 0.1	5.9± 0.1	5.2± 0.1	5.9± 0.1	5.4± 0.1
1	2	3	4	5	6	7	8	9	10	11	12
1	0.0287	0.0141	0.0018	0.0088	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2		0.7960	0.2593	0.6463	<0.001	0.0031	<0.001	<0.001	<0.001	<0.001	<0.001
3			0.3694	0.8371	<0.001	0.0064	<0.001	<0.001	<0.001	<0.001	<0.001
4				0.4848	<0.001	0.1023	<0.001	0.0015	<0.001	0.0026	<0.001
5					<0.001	0.0127	<0.001	<0.001	<0.001	<0.001	<0.001
6						0.0132	0.1458	0.4291	0.0185	0.3702	0.1458
7							0.0001	0.0998	<0.001	0.1338	<0.001
8								0.0281	0.3911	0.0230	1.0000
9									0.0020	0.9067	0.0281
10										0.0016	0.3911
11											0.0230

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