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INVESTIGATION OF INFLUENCING TO QUIT THE MILK PRODUCTION IN LARGE SCALE DAIRY FARMS

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INTRODUCTION AND OBJECTIVES

Today's large-scale dairy farms place great importance on using the most innovative and advanced feeding, housing, milking and veterinary technologies to produce milk economically and with high quality. By improving production indicators and reducing costs, we can achieve greater profitability in milk production. However, while producing sometimes extreme quantities of milk, farmers face a number of other problems. Globally, dairy cattle farms are experiencing a significant reduction in useful life and early cow deaths have become an increasingly common issue. In Hungary in 2021, the average useful life of the domestic Holstein-Friesian herd was 2.2 lactation periods and the average calving interval was 418 d. Due to these unfavorable values, a large number of heifers must be withdrawn from production. Consequently, almost all reproductively healthy heifers must be retained for breeding to replace non-productive cows, thereby maintaining herd size and production volume.

The topic selection was based on the short useful life of domestic Holstein-Friesian cow herds. Therefore, this study aimed to, I wanted to investigate in greater detail about the reasons for culling out of production in order to gain a broader insight into the most common reasons for culling in domestic cow herds.

The objectives of this research are to:

1. To identify the causes of the primary causes of culling in the different lactations in the farms surveyed. To examine the stage of lactation when the incidence of different medications is highest. To study and evaluate the evolution of the somatic cell count of the milk produced by the animals leaving production.
2. To investigate correlations between udder oedema severity and the following parameters: condition, calving semester, first calving age, gestation period, number of calving, length and diameter of udder teats, udder skin temperature, udder suspensory ligament score, fingerprint persistence, and udder and reproductive biological treatments.
3. To develop an evaluation method (the fingerprint test) to quantify the severity of udder oedema that is quick, cost-effective and easy to integrate into the daily milking routine on a large-scale dairy farm in Hungary, and supports the visual evaluation methods known so far.
4. To create a micro-simulation adapted to the farm conditions to help determine the optimal culling time of the animals, taking into account the pregnancy rate and milk production.
5. Comparison of the cow families of the surveyed farms with regard to the reasons for the culling. Examination of the relationship between the number of female offspring in cow families and age.

MATERIAL AND METHOD

Collection and analysis of production and culling data

The culling studies were conducted on twelve large-scale dairy farms in Hungary. The number of Holstein-Friesian dairy cows on the farms studied varied between 400 and 1500. Regarding geographical distribution, four farms were located in Csongrád-Csanád county, four in Veszprém county and four in Győr-Moson-Sopron county. The RISKA farm management system was used to collect breeding and production data. A properly filtered database was created for data analysis and reporting using Microsoft Excel 2019. In most cases, the IBM SPSS Statistic 26 program was used to statistically process the results. Visualization and textual evaluation of the results were performed using Microsoft Word 2019. I also used the GIMP- GNU Image Manipulation Program version 2.10.38. and Microsoft Paint to help me create the tables and graphs (charts, heat maps).

Scoring of udder oedema, examination of udder morphology

I investigated the presence and severity of udder oedema between December 2021 and November 2022 in a large-scale dairy farm in Csongrád-Csanád county. A total of 62 cows with udder oedema were identified in the group of cows two weeks before expected calving during the whole study period. The presence and severity of udder oedema was determined by physical examination of the udder using the four-point scale developed by Morrison et al. (2018). I scored the severity of oedema from 0 to 3, where 0 indicated no oedema, 1 indicated mild oedema, 2 indicated moderate oedema and 3 indicated severe oedema. Changes in udder oedema severity were monitored weekly for each selected individual before calving and up to 8 weeks after calving. For the cohort study, I included several variables as outcome variables for oedema. These were: fingerprint persistence, condition, udder length and diameter, udder skin temperature, suspensory ligament strength, age at first calving, gestation before testing, number of calving, calving semester (summer or winter semester), test day around calving, udder and reproductive biology diagnosis and veterinary treatments.

The persistence of the fingerprint is a measure of the firmness of the skin. It is determined by pressing the index finger into the oedematous area and measuring with a stopwatch how long it takes for the skin to return to its original condition. I expressed this time in seconds. The middle of each hindquarter of the cow's udder should be pressed in succession with the index finger for at least 2 seconds. The two values were averaged during data processing. I used a tape measure to measure the length of the udder teats and expressed the value in mm. The diameter of the udder teats is the width of the teats at the base, expressed in mm. For the measurement I used a digital caliper (MIB 02026065 Digital Caliper 150/0,01 mm DIN 862). I combined the data from the anterior and posterior udder teats in pairs when processing both characteristics of the udder teats. The udder skin surface temperature was measured on the hindquarters using a non-contact infrared thermometer (model AOV8711, power: DC3V, accuracy: +-0.2 °C, response time: 1 s, measuring distance: 2-5 cm). Temperatures are expressed in Celsius.

Statistical analysis

Baseline statistics on oedema were prepared for all the variables studied (including fingerprint persistence) by observing 294 cows (on average 4.7 measurements per cow for each parameter), recorded throughout the study period. For the latter, A one-factor analysis of variance was performed with the oedema score as the clustering variable. The Tukey HSD (honestly significant difference) post hoc test was employed to detect significant differences between classes of oedema score. The relationship between all indicators was then assessed by calculating correlation coefficients, taking into account each individual observation. I then performed a factor analysis (factor rotation: varimax normalized) to examine the associated variables. The change in factors associated with oedema (fingerprint persistence, test day) and the change in the extent of oedema over the study period were plotted graphically. The odds ratio for the degree of oedema was calculated from the persistence of the fingerprint. From a total population of 62 individuals, I analysed data from 50 cows with a maximum udder oedema score of 3. These results were compared with the results of the other cows (n = 12), which had a maximum udder oedema score of 2 points around calving. All variables (e.g. age at first calving, length of gestation, point of condition, length and diameter of udder teats, etc.) were treated as potential risk factors for severe (3-point) udder oedema and were tested using logistic regression (logit) with backward elimination until only variables with P-value <0.05 remained in the model. Parameter estimates, Wald statistics and odds ratio (OR) are reported with 95% confidence intervals (95% CI). All computer processing related to the udder oedema study was performed using Statistica version 14.0.0.0.15 (TIBCO Software Inc., 2020).

Methodology for the design of microsimulation

I was assisted in the creation of the microsimulation by researchers from the Department of Computer Optimization at the University of Szeged, Institute of Computer Science, TTIK. Data from six dairy farms were processed to create the simulation. The analysed parameters were collected from the RISKA farm management system. The following data were available: date of first insemination after calving, time between two unsuccessful inseminations, length of gestation, calving interval (in days) and success rate of inseminations. The study covered the period from 1980 to 2020. The micro-simulation was run on 1000 simulated (non-existent) cows, but the cow's life history was based on real farm data. To make the micro-simulation as realistic as possible, we had to take into account some basic parameters and their distribution, such as the length of gestation, the length of the service period, the length of the cattle's cycle or the first day of dry period.

One of the most important variables influencing the length of lactation of cows, the time interval from calving to first insemination (voluntary waiting time), was investigated. When processing the database of first insemination dates after calving, the following features had to be taken into account: a skewed distribution is obtained due to the use of synchronisation of insemination in some farms. The distribution is also distorted by the fact that the cow's heat is sometimes detected late, which prolongs the voluntary waiting time. The database had too little data and incorrectly recorded first insemination dates, which also needed to be addressed. Accordingly, the data were transformed by truncating the smallest values by 1% and then selecting the distribution that best fit them (Johnson SU). The average gestation period of cows is 285 days, but since the literature indicates an interval between 260 and 300 days (Norman et al., 2009; Vieira-Neto et al., 2017; Kašná et al., 2020), the real data were left between these two values and the distributions were fitted to them. Since the gestation period of the cow follows a normal distribution (Sobek et al., 2015), a bell curve was fitted to the data. We then examined the relationship between the pregnancy percentage and the number of inseminations. In the linear regression test, the coefficient of determination showed a medium (R2 = 0.36) strength of relationship, so in the simulation, the pregnancy rate was assumed to be independent of the number of inseminations.

Material and methodology for the comparative analysis of cow families

The population of cow families and the relationship between the number of female descendants of cow families and the reasons for culling were investigated on all 12 farms. A cow family is a group of female cattle that are descended from the same cow on the maternal side. In my study, the mother is a female that is the founder of a particular family line or has had at least one female offspring in her lifetime. For each herd, I traced the line of origin back to the founding cows (dams) of the herd, from 2020 back to 1990. I collected the parameters I needed from the RISKA farm management system, which were: mother (foundation cows and at least one female offspring born) ear number, date of birth and culling, culling method, culling code. The same parameters were collected for the female progeny. I traced the lineage back through up to 13 generations (from daughter to eighth granddaughter). For each mother, I counted the total number of female offspring, including daughters, grandchildren, great-grandchildren, great-great-grandchildren, great-great-grandchildren, etc. I counted the number of female offspring that were culled for various reasons (other reasons, reproductive biology, udder, locomotor, metabolic problems, or unfavourable milk production). I determined the earliest and latest culling ages and the average age of female offspring and produced basic descriptive statistics, and then also produced these broken down by farm. I then examined the relationship between the number of female offspring and age, using Spearman's correlation analysis. Finally, I selected the five most populous cow families from each farm and examined the relationship between the number of female progeny and their culling reasons frequency, for which I constructed a correlation matrix.

RESULTS AND DISCUSSION

Detailed analysis of the reasons for culling from milk production

When examining culling reasons, data from twelve sites were analyzed. The study processed six years of culling data, from 2015 to 2020.

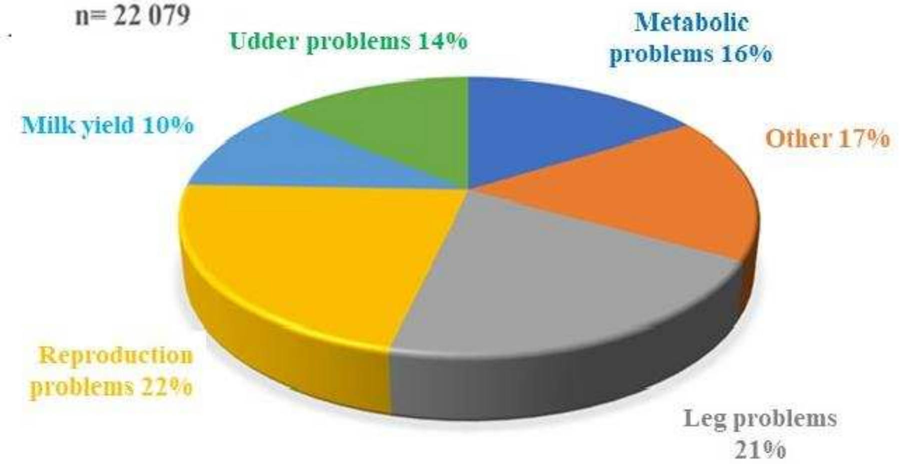

Figure 1: Evolution of the reasons for culling cows from the farms in the study (2015-2020)

The culling causes of the cows in the study were first examined collectively (see Figure 1), and found that the highest culling rate during the study period was 22% due to reproductive biology disorders. Leg problems were the next highest, accounting for 21%. 16% of cows left the farm due to metabolic diseases. 14% of the cows were removed from the herd due to udder problems and 10% due to inadequate production. The third highest proportion was observed in the 'other' category, but this is a combined group, which includes illnesses and conditions such as weakness of constitution, sudden cardiac arrest, pneumonia, heatstroke, septicaemia or drowning. I further investigated the proportion of different medications used at which stage of lactation. In *Table 1*, I have presented the percentages of drug treatments for each stage of lactation based on the data from the farms.

Table 1: Percentage prevalence of different medication regimens by lactation stage (2015-2020)

Number of calving	Rate of medication at different stages of lactation						
	1-50 (day)	51-100 (day)	101-250 (day)	251-400 (day)	401-600 (day)	600+ (day)	Total
1.	9.3 %	2.5 %	5.7%	6.1%	6.0%	1.3%	**30.9%**
2.	6.2%	2.8%	6.6%	5.9%	2.9%	0.3%	**24.7%**
3.	5.7%	2.2%	5.3%	5.3%	2.2%	0.3%	21.0%
>3.	6.4%	1.5%	6.1%	6.9%	2.2%	0.2%	23.4%
Total	**27.6%**	9.1%	23.8%	**24.2%**	13.3%	2.0%	100.0%

From the data in *Table 1*, it can be seen that the highest proportion of different drug treatments occurs after the first and second calving of the cow, 30.9% and 24.7% respectively. Regardless of the number of calving, it is observed that the first 50 days of lactation are the period in which the highest levels of medication occur. The second key period of lactation for the incidence of medication was the period between days 251 and 400 of lactation. During this period, a weakening of the immune system, which may cause, for example, more frequent metabolic problems, may be a response to the results I have obtained, or perhaps a worsening of pre-existing chronic diseases may be a reason for more frequent medication. The result of the Kruskal-Wallis test (p=0.0029) showed a significant difference between the rates of medication at each lactation stage. I also tested whether calving order affects the proportion of different drug treatments at each lactation stage. After performing the test, I found that the number of calving and the stage of lactation the cow is in does not significantly (p=0.6081) affect the frequency of medication in my case.

Results of the udder oedema test

Figure 2 shows the three variables associated in Factor 2. It can be clearly seen that oedema scores and fingerprint persistence seconds have very similar slopes by test day. As the least squares fit shows, these reach their maximum value a few days before calving. Then, by the 50th day after calving, both fall back to undetectable levels. No oedema if the skin returns to its original state immediately and there are no pits or indentations on the udder. My tests show that in mild oedema (point 1), the indentation (about 2-3 mm) disappears in 20-25 seconds. With moderate oedema (point 2), the slightly deeper indentation (about 4-6 mm) persists for about 45-50 seconds. If the oedema is severe (point 3) and the fingerprint test results in a deep pit (8-10 mm), it is estimated (see Figure 2 and the estimate in Table 2) that an average of at least 70-75 seconds is needed for the skin surface to return to its original state.

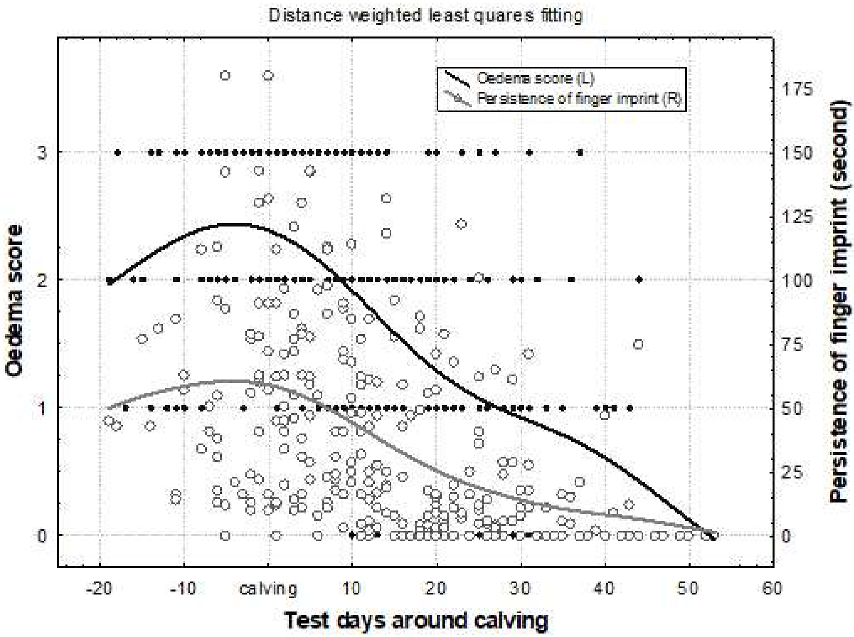

Figure 2: Distribution of oedema scores and fingerprint persistence (elasticity) in seconds by test day

When logistic regression was used, of the risk factors considered, only the persistence of the fingerprint showed a significant association with the degree of oedema. The Chi-squared value (12.2445, df=1) was highly significant (p<0.001) for the difference between the current model (48.68) and the model with only intercept (60.92). Thus, it can be concluded that the severity of oedema is significantly related to the persistence of the fingerprint, i.e. the elasticity of the udder skin. Parameter estimates, Wald statistics and odds ratios (OR) with 95% confidence intervals are presented in *Table 2*.

Table 2: Summary of the logistic regression model of the elasticity factor estimating the severity of udder oedema in cows

Risk factor	Estimate	Wald P-value	Odds ratio	95% CI OR[1]
Persistence of finger imprint	0.0412	0.0041	1.0421	1.0126-1.0725

[1] lower and upper 95% confidence interval odds ratio

The parameter estimation can be interpreted as in linear regression, i.e. an increase in oedema severity by 0.0412 points predicts a one second increase in the time required for the skin to return to its original state. The odds ratio was 1.0421. An odds ratio greater than 1 indicates that the classification is better than expected by randomness. Thus, the persistence of the fingerprint is longer for the most severe oedema (score 3), with the skin being the most insensitive, compared to moderate oedema (score 2). The overall percentage of correct classification was 87% (compared to 98% for oedema score 3).

Results of the microsimulation

The simulation was run with data from 1000 cows. Significant data from cows from different herds were analysed as a function of pregnancy rates and milk production reduction. When configuring the simulation, the real data of the farm was entered and the previously selected continuous distribution curves were fitted to the real data. For simplicity, the statistical calculations were performed using a gestation period of 275 days and a dry period of 60 days. In the simulation, the time of the culling decision and the pregnancy rate were investigated for the whole herd (1000 cows) and for the pregnant cows.

Table 3: Evolution of data for pregnant cows as a function of pregnancy rate (20-50%) and culling day (300 days-400 days) for non-pregnant cows.

	Culling date of non-pregnant cows from calving	Successful insemination			
		20%	30%	40%	50%
Number of cows in lactation	300	768	888	949	979
	350	841	929	971	989
	400	866	960	987	995
Total milk produced (kg) per cow per lactation	300	5 694 504	6 568 803	7 007 842	7 216 165
	350	6 259 145	6 891 374	7 180 072	7 294 644
	400	6 443 755	7 113 913	7 291 722	7 337 053
Average length of lactation (days)	300	360.80	347.47	335.24	324.73
	350	383.93	363.82	344.29	329.91
	400	401.40	367.32	339.49	329.65
Average daily milk yield per cow (kg) per full lactation	300	20.550	21.296	22.026	22.698
	350	19.377	20.381	21.477	22.364
	400	18.536	20.173	21.761	22.368
Average calving interval (days)	300	426.24	412.84	400.55	389.90
	350	439.78	425.16	407.62	394.21
	400	452.10	429.07	404.07	395.03
Milk yield calculated for the days of calving interval (kg)	300	17.395	17.924	18.435	18.904
	350	16.916	17.441	18.140	18.716
	400	16.458	17.270	18.283	18.666

The simulation model developed is able to predict the expected milk production under different pregnancy rates and culling days based on data from a given dairy herd. The model helps to improve the objectivity of the decision-making process, as culling decisions are often made subjectively. As shown in *Table 3*, the model assumes that only 20, 30, 40 or 50% of the 1000 cows are pregnant at each insemination. Insemination is attempted for 300, 350 or 400 days, and if the cow does not conceive within this period, no further insemination is attempted and the cow is culled. *Table 3* shows how the amount of milk produced between two calvings varies daily at different levels of pregnancy rates. It can be seen that, for example, if the cow is culled on day 400 and the pregnancy rate is 20%, this milk yield is 16.5 kg, and if the pregnancy rate is 50%, it is 18.7 kg. In our case, increasing the pregnancy rate did not result in an economically significant increase in milk yield. If we compare the pregnancy rates with the results of cows weaned on the same day, we can also conclude that there is no significant difference in milk yield between pregnancy rates of 20% and 50%. It can be seen that the length of lactation, i.e. the number of milk-producing days, can be extended by delaying the date of the culling decision. A steady decrease in daily milk yield is observed for both the 20% and 50% gestation rates. Increasing the pregnancy rate had a positive effect only on the calving interval of the parameters studied.

Results of the comparative analysis of cow families

The last study was a survey of dairy cow families on twelve dairy farms. In total, I studied the age trends of 308 500 female offspring of 58 986 mothers up to 1990 and 2020. I then looked at the reasons for culling female offspring of mothers (48 693 individuals) who had at least one offspring already cull. The number of these offspring was 222 377. Finally, I also examined in more detail the parameters of the five most populous cow families for each farm.

In the following study, I selected the five most populous cow families of each farm and examined the relationship between the number of female progeny and the frequency of their culling causes using a correlation matrix, the results of which are presented in *Table 4*.

Table 4: Correlation coefficients between the number of female offspring and their culling frequency

	1	2	3	4	5	6	7
1	1.00	-0.01	**0.65***	**0.54***	0.21	0.06	0.00
2	-0.01	1.00	-0.40	-0.26	-0.14	-0.24	-0.39
3	**0.65***	-0.40	1.00	0.39	0.27	-0.12	-0.06
4	**0.54***	-0.26	0.39	1.00	-0.13	0.34	0.46
5	0.21	-0.14	0.27	-0.13	1.00	-0.35	-0.38
6	0.06	-0.24	-0.12	0.34	-0.35	1.00	**0.75**
7	0.00	-0.39	-0.06	0.46	-0.38	**0.75**	1.00

Legend: 1 Number of female offspring, 2 Other reasons for culling, 3 Udder problems, 4 Reproductive problems, 5 Milk yield, 6 Metabotic problems, 7 Leg problems

I have analysed the relationship between female progeny and the frequency of culling causes in the most populous cow families on the farms. Udder problems showed a strong, positive, significant (r=0.65, p<0.001) relationship with the number of offspring. This relationship may suggest that the more populous a cow family is, the more likely it is that udder problems will occur among the offspring. A moderately strong, positive and significant (r=0.54, p<0.001) relationship was found between the number of offspring and reproductive problems, i.e. more populous cow families may also have a higher incidence of reproductive problems in offspring. The results suggest that more prolific cow families with more offspring may be genetically more susceptible to certain reproductive biology problems, but I have not investigated this. It may also be that more populous cow families are often better milk producers, and high milk production may negatively affect reproductive performance. It is likely that reproductive biology and udder problems may be more common in more populous cow families, due to the higher number of calvings. A very loose correlation was observed between the other causes of culling (production, metabolism, leg and other problems) and the number of offspring, i.e. these problems are probably not related to family size but rather to individuality, environmental factors and genetic factors.

I then also examined the relationship between culling causes in these 60 most populous cow families. I found a strong correlation ($r=0.75$) between the prevalence of metabolic and leg problems, meaning that metabolic problems can often lead to leg disease. In support of my hypothesis, Suthar et al. (2013) found that ketosis after calving increased the risk of lameness in dairy cows by 1.8-fold. A medium relationship ($r=0.39$) was found between udder problems and reproductive biology problems, i.e. the occurrence of udder problems may in some cases affect reproductive biology. Contrary to my results, Borş et al. (2024) found a highly significant difference between the pregnancy rate of cows with mastitis and the pregnancy rate of healthy cows (49.2% vs. 36.4%, $p<0.05$). Šarić et al. (2022) found that clinical mastitis significantly prolongs the time from calving to conception and increases the fertility index. This negative effect may contribute to early culling of cows.

NEW SCIENTIFIC RESULTS

Investigating the reasons for culling of Holstein-Friesian dairy cows in Hungary, the following new scientific findings can be identified:

1. The diameter of the anterior udder teats has been shown ($p=0.038$) to be positively related to the extent of udder oedema. The length of the anterior and posterior udder teats showed no correlation with the degree of oedema. Udder skin temperature showed a statistically proven ($p=0.007$) negative relationship with oedema severity. There is a significant ($p=0.014$), positive correlation between the prevalence of oedema and the frequency of reproductive biological treatments. The findings suggest that oedema as a metabolic disorder is more likely to be associated with reproductive biological diseases and treatments.
2. A moderately strong relationship was found between anterior and posterior udder teats length and calving semester (-0.50 and -0.39, respectively), between fingerprint persistence and day of test (-0.50), and between anterior udder teat length and udder skin temperature (0.42). I found that the persistence of the fingerprint (the elasticity of the udder skin) is significantly related to the severity of the oedema, so the fingerprint test can be used to assess the severity of oedema.
3. I found a loose positive but significant ($r=0.270$, $p<0.001$) relationship between the number of female offspring and mean age, a negative, moderately close, significant ($r=-0.502$, $p<0.001$) relationship between the earliest culling age, and a

close, positive, significant ($r=0.675$, $p<0.001$) relationship between the latest culling age.

4. Analysing the relationship between the frequency of female offspring and culling causes, I found that udder problems showed a strong, positive, significant ($r=0.65$, $p<0.001$) relationship, while reproductive problems showed a moderately strong, positive, significant ($r=0.54$, $p<0.001$) relationship with the number of offspring. When examining the relationship between the causes of culling of offspring, I found that there is a close ($r=0.75$) relationship between the prevalence of metabolic and locomotor problems, and a medium ($r=0.39$) relationship between udder problems and reproductive problems.

PUBLICATIONS IN THE FIELD OF THE DISSERTATION

Scientific publications in foreign languages

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