Revista de Ciências Agroveterinárias
Universidade do Estado de Santa Catarina (UDESC)

Research Article

Efficacy of artificial insemination in Holstein and Jersey cattle, considering necessary attempts for financial return on investment

Eficácia da inseminação artificial em bovinos Holandês e Jersey, considerando tentativas necessárias para retorno financeiro do investimento

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Submitted: August 13, 2024 | *Acceptance: April 19, 2025*

ABSTRACT

The technique of artificial insemination is one of the most important biotechnologies ever conceived for genetic improvement in production animals. Making it possible to increase the number of offspring of a single sire and to use semen after their death or reproductive inaptitude. However, females that have difficulties or do not conceive with the use of the technique generate more costs for the properties. It is justified to evaluate the ideal number of attempts on a female, before transferring her to natural breeding or disposal. The objective of this study was to evaluate the conception rates of cattle breeders from two rural properties, in order to analyze the factors involved and stipulate a number of adequate attempts to generate pregnancy, based on the relationship of costs and benefits, through the generation of mathematical formulas. This study was done with a total of 108 animals from two rural properties, of which 59 (54.6%) became pregnant after the first artificial insemination, 18 animals (16.7%) had pregnancy confirmed after the second and 14 animals (13%) after the third. The three replications result in a pregnancy rate of 84.3%, a result close to the ideal 85%. Finally, it can be concluded that establishing calculation bases involving the largest number of variables possible along with indicators of return on investment and return on investment period can help in the management of rural properties, as it can reveal the real situation of the activity and its operations.
KEYWORDS: Management. Biotechnology. Cost and benefit. Reproduction.

RESUMO

A técnica da inseminação artificial é uma das biotecnologias mais importantes já concebidas para o melhoramento genético em animais de produção. Possibilitando aumentar o número de descendentes de um único reprodutor e usar o sêmen após sua morte ou inaptidão reprodutiva. Porem fêmeas que possuem dificuldades ou não concebem com o uso da técnica geram mais custos para as propriedades. Justificando-se avaliar qual o número ideal de tentativas em uma fêmea, antes de a transferir para a monta natural ou o descarte. O objetivo deste estudo foi avaliar as taxas de concepção de matrizes bovinas de duas propriedades rurais, procurando analisar os fatores envolvidos e estipular um número de tentativas adequadas de se gerar prenhez, com base em relação de custos e benefícios, através da geração de fórmulas matemáticas. O presente estudo foi realizado com um total de 108 animais, provenientes de duas propriedades rurais, destes 59 (54,6%) ficaram gestantes após a primeira inseminação artificial, 18 animais (16,7%) tiveram prenhez confirmada após a segunda e 14 animais (13%) após a terceira. As três repetições resultam numa taxa de prenhez de 84,3%, resultado este próximo ao ideal de 85%. Por fim pode-se concluir que estabelecer bases de cálculos envolvendo o maior número de variáveis possíveis junto a indicadores de retorno sobre o investimento e prazo de retorno do investimento podem auxiliar na administração da propriedade rural, pois poderá revelar a real situação da atividade e de suas operações.
PALAVRAS-CHAVE: Administração. Biotecnologia. Custo e benefício. Reprodução.

DOI: 10.5965/223811712432025538

INTRODUCTION

Regardless of the field of activity, one of the most important factors for any investment is to know whether or not it is viable, as it intends to obtain profit and the consequent sustainability of the business (MORAIS et al. 2020). In agribusiness, the logic is no different. Specifically in the area of artificial insemination (IA), there is an imminent risk of loss, as it is a high-cost procedure. Thus, it requires a rigorous assessment of the financial factors and risks involved (MARMENTINI et al. 2023).

Among the potential tools available to rural producers to establish an accurate overview of costs and investments inherent to IA, we can mention the calculations of the various costs and universal tools used by companies in all segments, such as Return On Investment (ROI), which verifies whether the investment made by an individual or property has generated good effects through the analysis of the results and the Return on Investment Period (PRI) which calculates the period necessary to have a return on an investment, enabling the entrepreneur to focus on actions that bring greater return in less time (PROCHNOW & OLIVEIRA JÚNIOR 2022, SEBRAE 2022, SEBRAE 2023).

This work is justified by the fact that IA imposes on the producer the need to carefully evaluate the risks and the associated financial return. With the calculations of metrics such as Return on Investment (ROI) and Return on Investment (PRI), strategic analysis and safer decisions can be made (PROCHNOW & OLIVEIRA JÚNIOR, 2022).

The objective of this study was to evaluate the conception rates of cattle breeders from two farms in different attempts to obtain pregnancy through artificial insemination. And based on the work of REIS (2020) and GOTTSCHALL & SILVA (2014), it sought to analyze the factors involved and stipulate a number of appropriate attempts to generate pregnancy, based on the relationship of costs and benefits, through the generation of mathematical formulas. In order to defend that each rural property must perform a self-analysis, survey the variables involved in the reproductive cost and establish its own operational calculation systems in order to assist in decision making.

MATERIAL AND METHODS

The study was done in two rural properties, one at the coordinates -24.99489, -50.12790 using 73 Holstein females, aged 10 to 14 months, with minimum weights of 360kg and sizes from 1.19 to 1.37 meters and the other at coordinates -24.25090, -50.24171 using 35 Jersey females, aged 10 to 14 months, minimum weights of 230Kg and sizes of 1.10 to 1.40 meters. All insemination protocols were done between April 2021 and August 2021. According to the service offered by CLIMA TEMPO (2025) the minimum (°C), maximum (°C) and precipitation (mm) temperatures have regional averages of, respectively, 15, 23 and 75 in the month of April; 12, 20 and 93 in May; 11, 19 and 100 in the month of June; 10, 19 and 82 in July; and 11, 21 and 70 in August.

All animals submitted to artificial insemination protocols were tested through ultrasonography 30 days after the procedure, to confirm pregnancy. With the IA protocols redone on those with a confirmed negative pregnancy diagnosis.

In this study, the data of the animals that had positive pregnancy in the first, second and third attempts were evaluated, separating them into groups. Those considered as positive pregnancies from the fourth attempt were allocated together with those destined for crossbreeding with natural breeding or discarded from the herd. Those with confirmed pregnancy were separated into a secondary lot, ending their participation in this study.

To assemble the mathematical formulas, the bases described in the works of MARMENTINI et al. (2023), REIS (2020) and GOTTSCHALL & SILVA (2014) were used to create models that administrators can modify and adapt according to the reality and needs of each rural property.

And finally, the data was analyzed by conducting surveys of variables involved, such as costs related to the artificial insemination technique. At the same time as each of the attempts, the costs of maintenance of the females and costs with maintenance and acquisition of equipment.

RESULTS AND DISCUSSION

Artificial insemination

Artificial insemination is a first-generation reproductive biotechnology, being one of the most important tools ever conceived for the genetic improvement of farm animals, which has made it possible to increase the number of offspring of bulls. In this technology, the sperm are collected, processed (evaluated for defects and quality with the semen diluted in specific media, which allows a single ejaculate to be packaged and applied to a large number of females) and stored in a container with liquid nitrogen at a temperature of minus 196 degrees centigrade, which can be kept for years, even allowing bulls that died to continue producing offspring and also enabling the transport of semen doses over long distances, generating the possibility of producing offspring of a bull that resides in a distant region without the need to transport it to the females, enabling the export and import of genetics between different countries, even though there is a ban on the entry of live animals among them (HAMID et al. 2021, MAZUMDER et al. 2020, PARASCHIVESCU 2018).

IA allows the trade of semen doses, providing the possibility of improving genetics on rural properties, as the centers have a greater capacity of selecting bulls by progeny, facilitating the producers access to superior genetics when buying the semen doses of bulls selected by specialized companies. After selecting the females that will receive the sperm, the semen doses are thawed in a "water bath" with warm water and introduced into the uterus of the females using appropriate equipment for conception purposes. Artificial insemination also has the advantage of possibly avoiding the transmission of diseases between bulls and females (HAMID et al. 2021, MAZUMDER et al. 2020, PARASCHIVESCU 2018).

Evaluation of pregnancy rates in the studied properties

Reproductive efficiency (defined as the number of offspring produced during the female's life span in the herd, along with the age at first calving and interval between calvings) should ideally be established at rates higher than 85%, but the real-world situations have lower averages in extensive breeding, even with the use of IA, in which pregnancy rates are on average at 80%. Along with the association of hormonal protocols, which focus on synchronizing the estrous cycle, the biotechnique presents an average of 40 to 60% of pregnancy with a single application of semen (CASTRO et al. 2018, SOUSA et al. 2013).

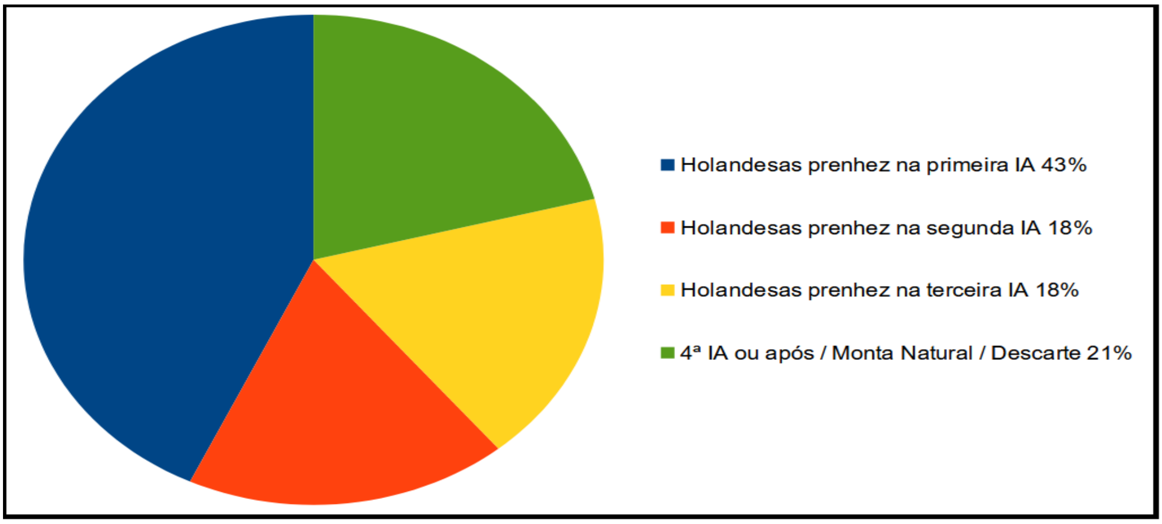
MÜLLER-SEPÚLVEDA et al. (2020) describe that the success of IA is related to different biological, environmental, social factors and the experience of inseminators. The genetic merit of bulls should also be characterized, associating the calving ease of the breeding female and the carcass merit (BERRY et al. 2020).

The fact that females do not conceive generates the frustrating need to repeat the IA process, resulting in greater economic costs. Many cattle breeders still face problems in the use of this technique, such as poor ability to adapt services, poor communication between those responsible, inability to select the desired breed and performing the procedures at inappropriate times, generating a low pregnancy rate (MAZUMDER et al. 2020).

In the Holstein breed animal farming, the percentage of pregnancy after the first insemination was 43%, in the second it was 18% and in the third it was 18%. When adding the first three inseminations, the total percentage is 79%. 21% were submitted to a fourth attempt, transferred to natural breeding or discarded (Figure 1).

Figure 1. Distribution of Holstein and artificial insemination (IA) that generated pregnancy.

When evaluating the data of the Holstein breeding property, it can be observed that it took three attempts to reach close to the average of 80%, but it was still below the ideal index of more than 85%.



On the Jersey cattle property, 34 (97.1%) had confirmed pregnancy up to the third insemination. Of these 28 animals (80%) had their pregnancy confirmed after the first artificial insemination, five (14.3%) were considered pregnant after the second artificial insemination and one (2.9%) after the third artificial insemination. Only one (2.9%) was submitted to other attempts, natural mounting or disposal (Figure 2).

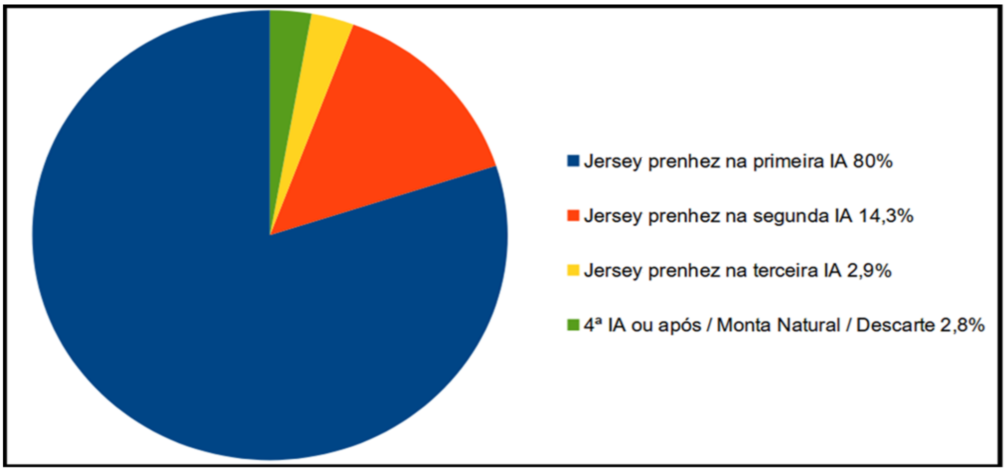


Figure 2. Distribution of Jersey and artificial insemination (IA) that generated pregnancy.

When evaluating the data from the Jersey breeding property, it can be observed that it took only one attempt to reach the average of 80%, and two to reach the ideal index of over 85%.

When evaluating the total number of animals (from the two farms participating in the experiment), it is possible to observe that, of 108 animals(100%), 59 (54.6%) became pregnant after the first IA, 18 (16.7%) after the second and 14 (13%) after the third. The remaining 17 (15.7%) did not have positive results until the third insemination, obtaining positive results from the fourth insemination, or placed to be fertilized with the use of bulls or even discarded from reproduction (Figure 3).

When we evaluate this data and add the percentages of three attempts, we have a total of 84.3% of pregnancies, which demonstrates that using three protocols makes it possible to achieve the goals of rates close to 85%.

The results were 5.6% lower than those obtained by HAMID et al. (2021) that of 221 cows and heifers inseminated, in their experiment, the overall conception rate was 60.2% (n = 133). Differences in values may occur due to issues such as environmental characteristics, herd, management techniques, inseminator's ability, correct detection of the animal's estrous cycle, protocol used, and other problems that may affect pregnancy rates, such as embryonic death followed by fetal resorption.

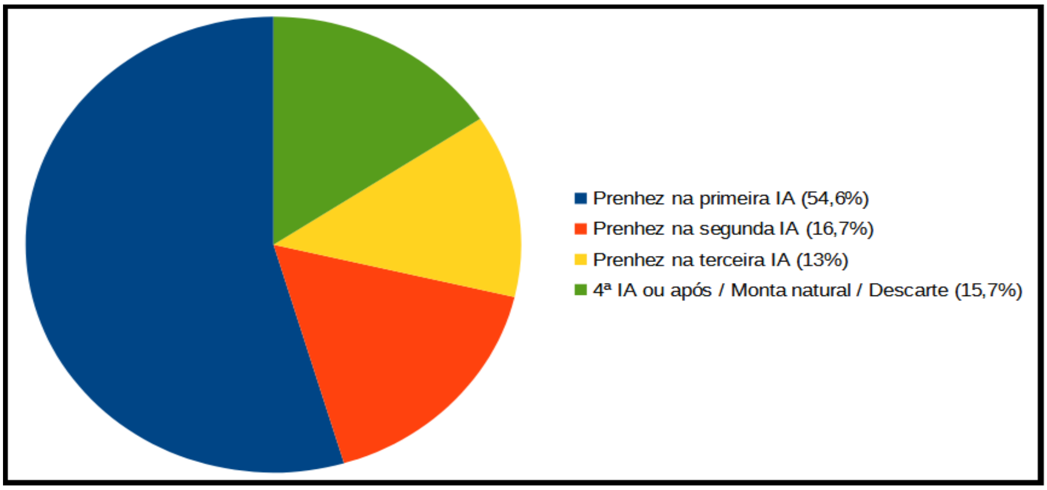


Figure 3. Distribution of the total number of animals and artificial insemination (IA) that generated pregnancy.

Economic analysis and its variables

Cost analysis

The economic evaluation of livestock production is crucial for understanding the true financial situation of a rural property. To ensure profitability, producers must be aware of and efficiently manage the key factors of production—land, labor, and capital—which directly influence profitability. By identifying bottlenecks, it is possible to focus managerial and technological efforts on enhancing production efficiency, reducing costs, and increasing profitability, all with the goal of fostering growth in the industry (Gomes et al., 2018).

COUTO et al. (2018) mention that in order to guarantee profit in agricultural activities, periodic accounting and analysis of economic and financial performance of production systems are essential. Making use of indicators that generate information and indicate increases or decreases in production, possibilities of reducing costs and increasing profitability. Enabling better control and management of the activity.

Cost assessment models in rural properties should be clearly organized to facilitate understanding and support informed decision-making. These models help assess the costs associated with production systems, particularly in full-cycle beef cattle operations. Costs can be categorized into variable costs, such as animal health management, inputs, and pasture maintenance, and fixed costs, including labor, fuel, and equipment depreciation, thus providing a solid foundation for economic calculations (Reis, 2020).

DIÓGENES (2019) states that in order to conduct an analysis of investments, a starting point, done through economic evaluations, should be considered for decision-making, regarding the fulfilment, or not, of projects. The analysis should consider the expenses and revenues generated by the investment in question, along with an understanding of the related risks and possibility of performing a simulation of costs and benefits. This will allow for a better understanding of the economic viability of projects, as well as their objectives, advantages, disadvantages and applications of the results obtained. The methodology of analysis and its stages must be well defined according to the situation.

When working in livestock (as well as in any enterprise) it is necessary to know that the investment made will take a certain period to generate results, regardless of whether they are related to structure, labor or animals. This factor should be considered in planning, evaluating the payback time, durability and financial returns. In the case of the present work, it can be observed that an evaluation of the costs of breeding, rearing, fattening and production is made. But, along with these factors, the time that the entire process will take must be visualized.

GOTTSCHALL & SILVA (2014) make an economic analysis in their work, establishing mathematical formulas, of different protocols of artificial insemination at a fixed time applied to beef heifers.

Cost to obtain pregnancy per animal (COPA)

The cost of obtaining pregnancy per animal (COPA) can be different between properties, as they are influenced by many factors such as variations in value due to market issues, management modes, labor, techniques used, number of repetitions and others. Among these, we can mention some:

- Cost of semen dose (CDS);
- Labor cost (CMO);
- Consumption of resources by the breeder in the period between calvings (CRMPP);
- Cost of the estrous cycle identification technique (CTIC);
- Cost of the hormonal protocol (CPH);
- Cost of purchase, maintenance and wear of equipment (CCMDE).

Cost of Semen Dose (CDS)

To have an approximate value of the cost of semen dose, it is necessary to evaluate the cost of the semen dose (VDS); cost of semen shipping per dose (CFSD), which must be obtained by the shipping cost (VF) divided by the number of doses transported (NDT); and cost of maintaining the semen cylinder in the period per semen dose (CMBS), which should be initially obtained by dividing the cost of maintaining the semen cylinder (CMB) - in a given period of time - by the number of days (ND), the result of this division should be divided by the number of doses maintained (NDM). Thus, we will have the formation of the following formulas:

- CDS = VDS + CFSD + CMBS
- CFSD = VF/NDT
- CMBS = (CMB/ND) / NDM

Labor Cost (CMO)

Evaluated in work characteristics, such as the number of employees and their salaries, the amount paid to the inseminator per dose applied and whether the labor is in-house.

Three types of formulas can have the following variables: employees' daily rate (VDF), which will be the sum of the salaries of the employees involved (SSF) divided by the number of (working) days of the month (NDM); amount paid per dose to the inseminator (VDI); cost of in-house labor (VMF), considering self-remuneration. It can be based on one of the other formulas:

• Daily cost of employees and inseminator per dose: CMO = (SSF/NDM) + VDI

• Daily cost of inseminators: CMO = SSF/NDM

• Family labor: CMO = VMF

Resource consumption by the breeder in the period between calvings (CRMPP)

Resources that the breeder consumes or needs such as food, mineral salt, common salt, pharmaceuticals, vaccines, veterinary medical care, care, among others. There is hardly a perfect assessment of all the data, but the more information that is analyzed, the clearer view is provided.

The administrator must have technical and scientific knowledge, as several data are difficult to collect, as is the case of food consumption in grazing animals, due to the difficulty of measuring how much pasture each animal consumes daily, remembering that pasture has its production cost either by investment or occupied area. In this way, some of the data can be based on scientific research published by other professionals.

Amount paid for veterinary and zootechnical consultations, drugs used, vaccines and others that are more easily recorded and must be carefully evaluated.

In this way, it is possible to generate some examples of calculations that can be applied to this analysis:

Pasture: CAP = RMAP / NAP or CAP = CMPAD x DPP

• Pasture feed cost (CAP);

• Grazing days between calving (DPP);

• Average cost of grazing per animal day, established by external research (CMPAD);

• Cost of restauration, management and fertilization of pastures (RMAP);

• Number of animals in the pasture during the period (NAP).

Silage: CAS = CSP / NAS

• Feed cost in silage (CAS);

• Cost of silage during the period (CSP);

• Number of animals fed with silage during the period (NAS).

Mineral salt: CSM = SMP / NASM

• Food cost with mineral salt (CSM);

• Cost of mineral salt during the period (SMP);

• Number of animals fed with mineral salt during the period (NASM).

Veterinary or zootechnical medical labor for the herd: CRMVZ = PPV/ NAA

• Cost of veterinary or zootechnical labor for the herd (CRMVZ);

• Number of animals served (NAA);

• Amount paid to the professional (VPP).

In-house labor: CMOI = VPP/NAPP

• Internal labor cost (CMOI);

• Number of animals present on the property (NAPP);

• Amount paid to professionals during the entire period (VPP), if the average is one calf cow per year, the amount must be computed based on their annual salary, including thirteenth and paid vacation.

All the data must be added to reveal the consumption of resources by the breeding animal in the period between calvings (CRMPP):

CRMPP=CAP+CAS+CSM+CRMVZ+CMOI+SVD

Costs of Hormonal Protocols (CPH)

Used in fixed-time artificial insemination techniques, the total amount paid by the protocol (VPP) should be divided by the number of animals that obtained pregnancy in the attempt (NAOP). Thus, we have: CPH= VPP/NAOP.

Cost of purchasing, maintaining, and equipment depreciation (CCMDE)

Evaluated according to the time of use of the equipment until the end of its working life, along with the amount paid for the acquisition and the cost of maintenance, it may be influenced by the quality of the equipment and the care taken to handle it. An average can be established based on past experiences to have a basis of cost, making use of evaluations by third parties and pre-established mathematical calculations. It will be possible to calculate this amount after calculating the acquisition costs (VA), maintenance through the years (VM), the time of use (TU) and the number of times it was used that resulted in pregnancy (NVURG). It is interesting to evaluate only the positive pregnancy diagnoses to know its cost to the herd, that is, the cost referring to the pregnancy of the female that did not become pregnant will be divided among those that became pregnant. Like this:

CCMDE = ((VA + VM) / TU) / NVURG

Cost to obtain pregnancy per animal (COPA)

According to the number of IA attempts that each female had to receive to be positive in the tests and, if applicable, the cost of natural mount (based on a percentage referring to the value of the bull and the cost of maintaining it).

Calculation for each IA attempt using hormonal protocols:

T = CDS + CMO + CPH

Calculations for animals that obtained pregnancy with only one, two or three IA attempts respectively, with the use of hormonal protocol:

COPA = T + CRMPP + CCMDE

COPA = T1 + T2 + CRMPP + CCMDE

COPA = T1 + T2 + T3 + CRMPP + CCMDE

The use of the bull after IA attempts, with or without the use of the protocol, should be analyzed. First, evaluating the cost of the bull that generated pregnancy (CMTGP), based on the amount paid for the acquisition of the bull (VT), the cost of maintaining the bull during its life (VMTV), referring to everything that was spent (such as drugs, food, veterinary assistance, labor, among others). The calculation is similar to that of the consumption of resources by the breeder in the period between calvings (CRMPP) and number of pregnancies generated by the animal during its lifetime (NGTV). The value referring to the cost of bull riding can be based on research by other professionals.

This way, the formula is established:

CMTGP = (VT + VMTV) / NGTV

When using natural mounting, after the third IA attempt with the use of hormonal protocol, the following formula will be used:

COPA = T1 + T2 + T3 + CRMPP + CCMDE + CMTGP

Yield analysis with cattle farming

To analyze the financial income generated by the animal (R), it is necessary to know the value of the animal (VA) established by various aspects (market, genetics, production, among others). The cost from conception to weaning. And the animal's resource consumption (CRA). The calculation is done in a similar way to the resource consumption by the breeding animal in the period between calvings (CRMPP). In the case of dairy females, the value of their milk production (NPV) from the first to the last lactation should be considered. It should be aware that if the animal dies, its value will be null. We have the following formulas:

R= VA - COPA - CRA and R = VA + NPV - COPA - CRA

Return on investment

Performing an accounting analysis to assess the financial return on investments made in the IA process is essential to justify the practice and correct or adapt situations that may be generating financial loss. Thus, it is possible to make safer decisions for the rural property, through the effects that the investments will produce and the performance history of past experiences.

According to SEBRAE (2023), the Return on Investment (ROI) is the rate calculated from accounting data that measures the return to the business on the invested capital (in other words, it verifies whether the investment made by an individual or property generated good effects through the analysis of the results). The calculation of ROI must be based on two data, namely, the total cost of the action to be evaluated and the revenue obtained from this investment. Through this it is possible to determine the maximum cost of funding that may be interesting for the company, and if this cost is greater than the ROI, the company will hardly be able to replace the amount invested within the negotiated period. However, the evaluation done through the ROI method has limits, due to the fact that factors such as the duration of the investment, seasonality and variations in values determined by inflation are not considered. Return on Investment (ROI) is expressed as the ratio of net income to total assets. And to turn this result into a percentage, just multiply it by 100. The formula for calculating ROI is as follows:

ROI = (LC – INV) / INV, where:

- LC: Profit
- INV: Investment

Return on Investment Period

According to SEBRAE (2022), the Return on Investment Period (PRI) is another very useful tool for investor decision-making. It calculates the period necessary to have a return on an investment. Providing the entrepreneur with a forecast of the time that the invested resources will take to generate income and allowing him to focus on actions that bring greater return in less time. The PRI is calculated by dividing the amount invested and the annual cash flow. Thus, the formula can be observed:

PRI = VI / FAC, where:

- VI: Amount invested (VI)
- FAC: Annual Cash Flow

Analysis between the suggested calculation bases and the two properties described

By establishing a line of thought between the two properties analyzed and the suggested calculation models, it is possible to make a comparison between the situations presented in the Holstein cattle breeding institution and in the Jersey cattle breeder.

When combining the aspects revealed by the analysis of pregnant animals on the properties and those defended by the calculations, it should be noted that the costs of obtaining pregnancy by repeating IA attempts may become uninteresting for billing, due to the cost-benefit issue, because up to the third attempt, the pregnancy rates have reached close to the ideal average and repeating from this point may not generate the expected revenue, mainly due to the fact that there are animals that have greater difficulty in resulting in positive pregnancy with this technique and it would be more profitable to make use of the bull or discard them.

It is worth mentioning that the calculations described (along with those that can be created or adapted by the managers) and the indicators mentioned are only complementary ways of evaluating the economic reality of the property and its production, as they make it possible to provide a better view.

CONCLUSION

Establishing calculation bases involving the largest number of variables possible (even though they make calculations more difficult and force the manager to have greater control over investments and income) along with indicators of return on investment and return on investment period can help in the management of rural properties, revealing the real situation of the activity and its operations.

In the rural properties analyzed, most of the bovine females obtained positive pregnancy, by performing artificial insemination, in the first three attempts of the technique. When evaluating the two simultaneously, the total number of animals came close to the 85% pregnancy rate, described as ideal.

When comparing the properties using calculations in relation to the results of artificial insemination and pregnancy rates in the attempts, it is perceived that the Jersey cattle breeding property is more efficient in the reproductive matter because it requires a smaller number of attempts at artificial inseminations per animal.

New research will always be necessary in relation to the variables (such as climate, feeding, health, genetics) that influence the reproduction and production of animals and should also consider the sectors related to the market and management since every variable influences the financial result.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology and formal analysis, João Luiz Androukovitch, Guilherme Pepino Bastos and Ângelo José Penna Machado; software and validation, Guilherme Pepino Bastos; investigation, João Luiz Androukovitch and Guilherme Pepino Bastos; resources and data curation, João Luiz Androukovitch; writing - preparation of the original draft, Guilherme Pepino Bastos and Ângelo José Penna Machado; writing - review and editing, Guilherme Pepino Bastos and Ângelo José Penna Machado; visualization, João Luiz Androukovitch, Guilherme Pepino Bastos and Ângelo José Penna Machado; supervision, João Luiz Androukovitch and Ângelo José Penna Machado; project management, João Luiz Androukovitch; fundraising, João Luiz Androukovitch. All authors have read and agreed with the published version of the manuscript.

FINANCING

This work was not supported by any funding agency.

STATEMENT OF THE INSTITUTIONAL REVIEW BOARD

Not applicable. The data comes from records of the properties participating in the project.

INFORMED CONSENT STATEMENT

Not applicable as this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available upon request.

ACKNOWLEDGEMENTS

We thank God and all those who made this study possible.

CONFLICTS OF INTEREST

The authors João Luiz Androukovitch; Guilherme Pepino Bastos; Ângelo José Penna Machado of the manuscript entitled " Efficacy of artificial insemination in Holstein and Jersey cattle, considering necessary attempts for financial return on investment" declares that there are no conflicts of interest of a personal, commercial, academic, political and/or financial nature, in the process of appreciation and publication of the referred article.

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