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Use of artificial genetic algorithm for genetic improvement of cattle in Angola

Uso do algoritmo genético artificial para o melhoramento genético de gado bovino em Angola

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ABSTRACT: The general objective of this work is to use the artificial genetic algorithm as a tool for the genetic improvement of cattle in Angola.The use of this tool for genetic improvement of cattle aims to increase meat and milk production through the selection and crossing of animals with desirable characteristics.The Angolan government has invested in livestock development programs, including cattle restocking and genetic improvement.Genetic improvement of livestock in Angola, as in other regions, seeks to improve the genetic characteristics of animals to increase the production of meat, milk, or other desired characteristics, such as precocity and meat quality. This is done through the selection of animals with good characteristics, the use of techniques such as artificial insemination, and the management of herds to ensure genetic evolution over time. Thus, genetic improvement has contributed not only to generating a more productive and precocious animal, but also to gain resistance to adverse environments, diseases and parasites.The results demonstrate that artificial insemination has been the most successful and effective reproduction biotechnology in animal production in Angola, *being responsible for* genetic increase rates in dairy farming of around 1.0 to 1.5%.It has revolutionized the commercial dairy cattle population in recent years, allowing the dissemination of superior genotypes on a large scale.
Keywords: Livestock, Artificial insemination, Artificial intelligence.

RESUMO: O objectivo geral deste trabalho é utilizar o algoritmo genético artificial como ferramenta para o melhoramento genético de bovinos em Angola. A utilização desta ferramenta para o melhoramento genético de bovinos visa aumentar a produção de carne e leite através da selecção e cruzamento de animais com características desejáveis. O governo angolano tem investido em programas de desenvolvimento pecuário, incluindo repovoamento de gado e melhoramento genético. O melhoramento genético do gado em Angola, como em outras regiões, visa melhorar as características genéticas dos animais para aumentar a produção de carne, leite ou outras características desejadas, como precocidade e qualidade da carne. Isso é feito por meio da selecção de animais com boas características, do uso de técnicas como a inseminação artificial e do manejo dos rebanhos para garantir a evolução genética ao longo do tempo. Assim, o melhoramento genético tem contribuído não só para gerar um animal mais produtivo e precoce, mas também para ganhos ligados à resistência a ambientes adversos, doenças e parasitas. Os resultados demonstram que a inseminação artificial tem sido a biotecnologia de reprodução mais bem-sucedida e eficaz na produção animal em Angola, sendo responsável por taxas de aumento genético na pecuária leiteira em torno de 1,0 a 1,5%. Ela revolucionou a população de gado leiteiro comercial nos últimos anos, permitindo a disseminação de genótipos superiores em larga escala.
Palavras-chave: Desenvolvimento pecuário, Inseminação artificial, Inteligência artificial.

INTRODUCTION

Bovine genetics is the branch of animal genetics that studies and applies the principles of heredity in livestock. The physical and productive characteristics of cattle are passed down from generation to generation (Weiblen y Nogueira, 2015).

The goal of cattle genetic improvement in Angola is generally to achieve higher levels of production, productivity, and/or product quality. Genetic improvement is an essential tool for producers who wish to increase livestock efficiency and profitability (Minagrif, 2021).

The genetic improvement of cattle, throughout history, has gone through several phases, from initial domestication to the application of modern selection and crossing techniques. Evolution aims to optimize characteristics such as meat and milk production, adaptability and disease resistance, boosting livestock productivity and efficiency (Rosa *et al.*, 2013; Larson y Fuller, 2014).

There are four phases of genetic improvement:

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a. Domestication and empirical selection: The history of genetic improvement begins with the domestication of cattle, where initial; selection was based on visible and useful characteristics for subsistence;

b. Racial standardization: From the 19th century onwards, with the introduction of European and zebu cattle in Brazil, there was an effort to standardize breeds and desirable; characteristics, such as shape and beauty;

c. Selection and crossing: Artificial selection began to be used to choose animals with superior characteristics for reproduction, seeking to establish desirable traits and improve production;

d. Scientific advances: The development of genetics and biotechnology has allowed a greater understanding of heredity and the application of techniques such as artificial insemination, in vitro fertilization and embryo transfer, accelerating genetic progress (Baruselli, 2020).

The selection of genetically superior animals allows for the improvement of characteristics of economic interest, such as weight gain, fertility, disease resistance and carcass quality, directly impacting the productivity and competitiveness of the production system. However, for a genetic improvement program to be successful, it is essential to understand its principles, define clear objectives and adopt appropriate techniques. In this work, we will cover the essential concepts, main steps and tools available to accelerate the genetic progress of the herd (Zart *et al.*, 2013).

Animal production can be increased in two fundamental ways:The first is by improving the environment in which the cattle are conditioned, through nutritional, sanitary, and/or reproductive advances, and this is a temporary and costly process due to labor and inputs.The second is through genetic improvement, carried out using an artificial genetic algorithm, through genetic selection, mating systems and crossing techniques, in which improvements require more time than the first, however, their gains are practically permanent (Zart *et al.*, 2013).

The herd'sgeneticheritageisdirectlyrelated to the efficiency of the productionsystem. In thiscontext, good animal management, health, and nutritionpracticespromotemaximumexpression of the cattle'sgeneticpotential.

The genetic algorithm (GA) is a method for solving both constrained and unconstrained optimization problems that is based on natural selection and biologicalevolution. The GA repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. We can apply the GA to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, nondifferentiable, stochastic, or highly nonlinear (Tomoiagă *et al.*, 2013).

Objectives and benefits of genetic improvement of cattle in Angola

a. Increased productivity: Improve the production of meat, milk or other desired characteristics;

b. Improve quality: Improve meat quality, such as tenderness or milk quality;

c. Disease resistance: Select animals that are more resistant to diseases, reducing losses due to illness;

d. Food security: Contribute to food security and the reduction or dependence on meat and milk imports;

e. Precocity: Reduce growth time and time to reach reproductive age, increasing production efficiency.

METHODOLOGY

This work is a bibliographic review that aims to survey available information and data on the use of artificial genetic algorithms for the genetic improvement of cattle in Angola. This is a narrative review, in which the results obtained based on readings and observations of available technical-scientific information were presented, providing a review of the most current data on the topic addressed. The research was carried out based on the literature review of scientific articles and academic publications from national and international universities and research institutions. The data were searched and compiled using Google and Google Scholar. The keywords and indexes used during the search were artificial genetic algorithm, cattle genetic improvement, and Angola. After reading the materials found, files in Portuguese and English relevant to the topic to be discussed were pre-selected and later used as a database in writing the review. The criteria for selecting the files were the date of publication within the stipulated period, preferably the most recent, free access for the community and coherence with the topic studied. Articles were excluded that, after critical and analytical reading of the title and abstract of the work, they presented duplicate information, were not freely accessible to the public, were outside the central theme analyzed, or had a relatively very old publication date.

Genetic Algorithm

GAs are a branch of evolutionary algorithms and, as such, can be defined as a search technique based on a metaphor for the biological process of natural evolution

In GAs, populations of individuals are created and subjected to genetic operators: selection, recombination (crossover), and mutation. These operators use a characterization of the quality of each individual as a solution to the problem at hand, called evaluation, and will generate a process of natural evolution of these individuals, which should eventually generate an individual that characterizes a good solution (perhaps even the best possible) to our problem. (Gerges*et al.*, 2018).

Put another way, we can say that GAs are search algorithms based on the mechanisms of natural selection and genetics. They combine survival of the best with a structured exchange of genetic information between two individuals to form a heuristic search framework (Burkhart y Ruiz, 2023).

Reproduction and mutation are applied to selected individuals within our population. Selection should be done in such a way that the fittest individuals are selected more frequently than the less fit ones, so that their good traits predominate within the new population of solutions. Under no circumstances should the less fit individuals be discarded from the breeding population. This would cause rapid genetic convergence of all solutions to the same set of traits and would prevent a broader search of the solution space (Tavares *et al.*, 2004).

Genetic convergence translates into a population with low genetic diversity that, because it possesses similar genes, cannot evolve except through the occurrence of random positive mutations. This can be translated into another interesting concept: loss of diversity, which can be defined as the number of individuals that are never chosen by the parental selection method. The greater the loss of diversity, the faster the convergence of our GA (Luque-Rodriguez et al., 2022).

Operation of a GA

The operation of a GA can be summarized algorithmically through the following steps Jansen y Weyland (2007):

a. Initialize the chromosomepopulation.
b. Evaluateeachchromosome in the population.
c. Selectparents to generate new chromosomes.
d. Applyrecombination and mutationoperators to theseparents to generate the individuals of the new population.
e. Delete the oldmembers of the population
f. Evaluateall new chromosomes and insertthemінto the population.
g. If time is up, or the bestchromosomemeets the performance requirements, returnit. Otherwise, return to step c).

Figure 1 represents the operation of aGA.

In a GA the process usually starts from a population of randomly generated individuals and is an iterative process. In each generation, the fitness of each individual in the population is evaluated. Fitter individuals are stochastically selected from the current population. The new generation is used in the next iteration of the algorithm. Commonly, the algorithm ends when a maximum number of generations has been produced or a satisfactory fitness level has been reached for the population (Pétrowski y Ben-Hamida, 2017).

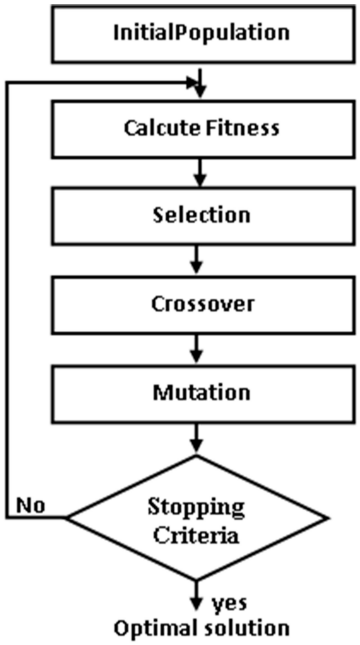

Figure 1. Operation of GA.

Stages and techniques for genetic improvement

a. Selection: Identification and selection of animals with superior genetic characteristics, such as increased growth, weight gain, meat quality, or disease resistance.
b. Reproduction: The use of techniques such as artificial insemination, embryo transfer, or other strategies to ensure the multiplication of selected animals and the transmission of their genes to the next generation.
c. Herd management: The organization and management of herds, including the rearing and fattening of animals, the use of suitable pastures, and disease prevention to ensure the proper development of the animals and the perpetuation of genetic evolution.

Cattle selection methods for genetic improvement

a. Ancestral Selection: This method uses the performance of ancestors to identify traits with low or medium heritability. During this process, information is collected from the ancestors of a given bovine, when individual information about the animal is not available.
b. Selection by relatives: In this method, cattle are selected based on information from the production records of their relatives (phenotypic values).
c. Progeny Selection: This selection evaluates the genetic value of the male based on the behavior of his progeny. Mainly because the father offers half of his genetic material to his children. This progeny test is the ideal method for selecting males, especially when a desired attribute is manifested only in the female.

d. Individual selection: Individual selection is based on the phenotypic value of the cattle (production records). This method is the most used for genetic improvement of cattle. Although it is essential to define characteristics that can be measured in the individual, individual selection is basically limited to phenotypic values. In fact, the selection of an individual occurs by anticipating its genotype based on its phenotype.

Use of the artificial insemination technique for cattle

The rapid spread of this technology is due to a combination of genetic, economic, and technical factors. Its use has allowed for improved progeny testing and, consequently, the evaluation of the genetic merit of bulls in many herds. Furthermore, it allowed the best genotypes to be made available to the entire animal population. According to Baruselli *et al.* (2019) genetic research benefits from this same technology, as it allows the use of bulls in various herds.

On the other hand, this technology has been the most successful and effective reproductive biotechnology in animal production, being responsible for genetic increase rates in dairy farming of around 1.0 to 1.5% per year. It has revolutionized the commercial dairy cattle population over the past 50 years, allowing the widespread dissemination of superior genotypes. In some countries, practically 100% of dairy cows are mated using this same technology.

Overview of artificial insemination in Angola

Artificial insemination of cattle in Angola is a practice to improve production and genetics by introducing semen from selected bulls into the cow's uterus without direct contact (De Carvalho et al., 2021).This method allows mating with more adapted and better-performing breeds, but requires personnel training, specific materials (such as liquid nitrogen cylinders for frozen semen) and the correct observation of fertility and sexual desire for insemination at the ideal time, as indicated by other livestock organizations. It is the mechanical introduction of a bull's semen directly into the cow's reproductive tract, avoiding natural mating (Ferreira *et al.*, 2021).

Objectives of artificial insemination in Angola (Minagrif, 2021)

a. Genetic improvement: Allows the use of semen from high-quality genetic bulls and breeds better adapted to Angola's environmental conditions, promoting more productive and resilient cattle.

b. Greater reproductive efficiency

Process Steps

a. Identifying fertility and sexual desire: The cow is closely observed to identify signs of fertility and sexual desire (being receptive to mating and not mounting other cows);

b. Semen preparation: The semen is frozen in straws inside a liquid nitrogen tank;

c. Semen introduction: The semen is introduced into the cow's uterus using an applicator.

Required materials

Nitrogen cylinder, semen straws, disposable gloves, tweezers.

General considerations

a. Training: The technique requires trained personnel familiar with animal anatomy and equipment handling;

b. Hygiene: It is essential to maintain proper cleanliness of materials, and unsanitary conditions can compromise fertility.

RESULTS

Artificial insemination of cattle in Angola offers results in genetic improvement and productivity, allowing the use of semen from superior bulls, the crossing of breeds adapted to the local climate with breeds from other countries, and the use of semen from high-value animals. To be successful, artificial insemination in Angola, as anywhere, requires proper management, including nutrition, health, animal comfort and the use of appropriate equipment, as well as trained personnel.

Main advantages:

a. Genetic improvement: Allows the introduction of desirable characteristics into the herd, such as greater production potential, by using semen from genetically superior bulls.

b. Bull utilization: Semen from a single bull can be used to inseminate hundreds of cows, optimizing the use of the bull and reducing the costs of maintaining a bull on the farm.

c. Breed crossing: Allows the combination of semen from European bulls with cows raised in Angola, resulting in animals with greater hardiness and productivity, adapted to tropical conditions.

d. Use of special semen: Allows the use of semen from bulls that have died or are unable to be naturally bred, ensuring the continuity of genetic improvement, as is the case with fixed-time artificial insemination that allows ovulation even in cows without regular cycles.

Studies show that to obtain the best results, the following conditions are necessary:

a. Management and qualified personnel: Artificial insemination requires well-trained operators and the use of specific equipment to ensure the health of the herd and the efficiency of the process.

b. Sanitation: Inadequate cleaning of instruments or unsanitary conditions can decrease fertility and

increase the spread of disease, especially if the semen is not from properly tested bulls.

c. Individual registration: It is essential to have an individual registration system for each animal, for adequate control and monitoring of each individual.

The use of artificial genetic algorithms as a tool for the genetic improvement of livestock in Angola aims to increase meat and milk production through the selection and crossing of animals with desirable characteristics (Minagrif, 2021). Reproductive biotechnology has been successful in animal production, being responsible for genetic increase rates in dairy farming of around 1.0 to 1.5% per year, as it has revolutionized the commercial dairy cattle population in the last 50 years, allowing the dissemination of superior genotypes on a large scale. In some countries, virtually 100% of dairy cows are mated using this technology.

Figure 2 represents artificial insemination in cattle.

Figure 2. Artificial insemination in cattle. https://www.cpt.com.br/ cursos-bovinos-gadodeleite/inseminacao-artificial-em-bovinos-convencional-e-em-tempo-fixo

DISCUSSION

Artificial insemination of cattle in Angola can improve productivity by disseminating superior genetic traits, reduce breeding stock maintenance costs, and minimize disease transmission. However, its implementation requires investment in personnel training, strict hygiene protocols and technical monitoring, ensuring that the females to be inseminated are in perfect health and estrous cycle conditions.

Artificial insemination has the following benefits:

a. Genetic improvement: Allows the use of semen from proven bulls with superior characteristics, disseminating high-quality genetics throughout the herd and increasing cattle productivity and quality.

b. Cost reduction: Reduces the need to keep a large number of bulls on the property, reducing feed and infrastructure costs.

c. Health safety: Minimizes the risk of disease transmission through semen, protecting the health of the herd.

d. Flexibility in management: Allows for the organization of mating and the synchronization of births, facilitating the health and nutritional management of the herd.

The following requirements are proposed for better artificial insemination:

a. Technical training: It is necessary to invest in team training to master advanced artificial insemination techniques and invest in training programs.

b. Animal health: It is essential to inseminate only females in perfect health, especially those without irregularities in their estrous cycle.

c. Strict hygiene practices: Require strict sanitary control at all stages, including semen handling, material thawing, environmental cleaning, and instrument sterilization.

d. Infrastructure: Requires the availability of adequate equipment and supplies, such as quality semen, laboratories for processing and storage, and qualified veterinarians.

e. Process management: It is necessary to implement an efficient management system, which includes accurate heat detection or the use of fixed-time synchronization protocols to maximize success rates.

CONCLUSIONS

We can conclude that the use of genetic algorithms for the genetic improvement of cattle is a powerful tool for transforming livestock farming, making it more efficient, profitable and sustainable. The researchresults demonstrate that, artificial insemination has been the most successful and effective reproduction biotechnology in animal production in Angola, being responsible for genetic increase rates in dairy farming of around 1.0 to 1.5%. It has revolutionized the commercial dairy cattle population in recent years, allowing the dissemination of superior genotypes on a large scale. By investing in genetic improvement, livestock farmers can optimize production, reduce costs and add value to their products, contributing to the development of the sector. Furthermore, the producer not only ensures better economic results, but also contributes to the sustainability and future of livestock farming. Genetic improvement is one of the most powerful strategies for increasing livestock productivity and profitability.

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