DOI: 10.5965223811712342024625

Revista de Ciências Agroveterinárias 23 (4): 2024
Universidade do Estado de Santa Catarina

Impact and prospects of reproductive biotechnologies on swine production in South America

Impacto e perspectivas das biotecnologias reprodutivas na produção suína na América do Sul

Keyro Alberto Melendez (ORCID 0000-0002-5045-6511), Victor Alberto Ramos (ORCID 0000-0002-9830-2386)

National University Micaela Bastidas of Apurimac, Peru. *Corresponding author: kmelendez@unamba.edu.pe

Submission: 01/08/2024 | Acceptance: 16/08/2024

ABSTRACT

In the evaluation of reproductive biotechnologies in pigs in South America, 72 key articles were selected through a comprehensive literature review and a sampling formula was used to ensure representativeness. Data collected from databases such as Scopus and Web of Science, assessed usinga Likert scale and a reliability of 70.1% according to Cronbach's Alpha, reveal that artificial insemination (AI) is the most widely adopted technique, with more than 90% of commercial farms using it. In contrast, embryo transfer (ET) and in vitro fertilization (IVF) have limited adoption, with only 10% of farms applying them due to high costs and low efficiency. The multiple correspondence analysis (MCA) indicates that 55% of publications focus on AI and ET, whereas only 25% articles focused on IVF. The perception of information quality showed that 70% of the respondents considered articles on AI clear, compared to only 40% for IVF. In conclusion, while AI remains prevalent and effective, the adoption of ET and IVF faces significant barriers, suggesting an urgent need to improve the accessibility and efficiency of these advanced technologies and strengthen research in less-covered areas.

KEYWORDS: reproductive biotechnology; swine; insemination; genetic improvement; embryos.

RESUMO

Na avaliação das biotecnologias reprodutivas em suínos na América do Sul, foram selecionados 72 artigos chave por meio de uma revisão exaustiva da literatura e uma fórmula de amostragem foi utilizada para garantir a representatividade. Os dados coletados de bases como Scopus, Web of Science, Scielo, Redalyc e relatórios de pesquisa (teses), foram avaliados com um questionário (em escala Likert), com uma confiabilidade de 70,1% segundo Alfa de Cronbach, revelando que a inseminação artificial (IA) é a técnica mais adotada, com mais de 90% das operações comerciais utilizando-a. Em contraste, a transferência de embriões (TE) e a fertilização in vitro (FIV) mostram uma adoção limitada, com apenas 10% das operações aplicando-as devido a custos elevados e baixa eficiência. A análise de correspondência múltipla (ACM) indica que 55% das publicações se concentram em IA e TE, enquanto apenas 25% abordam FIV. A percepção da qualidade da informação mostra que 70% considera que os artigos sobre IA são claros, em comparação com apenas 40% para FIV. Em conclusão, enquanto a IA continua predominante e eficaz, a adoção de TE e FIV enfrenta barreiras significativas, sugerindo uma necessidade urgente de melhorar a acessibilidade e eficiência dessas tecnologias avançadas e reforçar a pesquisa em áreas menos cobertas.

PALAVRAS-CHAVE: biotecnologia reproductiva; suínos; inseminação; melhoramento genético; embriões.

INTRODUCTION

The planet is currently home to almost 7.5 billion people, and this number is expected to exceed 9 billion by 2050. In this scenario, the Food and Agriculture Organization of the United Nations (FAO) estimates that global food production will need to increase by 60% to 70% over the next three decades to meet growing demand (RENTERÍA et al. 2021). Reproductive biotechnologies are emerging as innovative and sustainable tools to address this challenge, allowing high-quality genetics to be propagated more quickly and efficiently than conventional animal breeding methods. These technologies improve the quality and productivity of livestock, facilitating access to superior genetic material, and optimizing the use of available resources. (CÓRDOVA et al. 2022).

Swine biotechnology has a particular significance both in the biomedical field and in the swine industry (ROSETE et al. 2021), leading to a growing demand for new technologies that drive knowledge and application in this area, as well as continuous improvement and effective application of existing technologies (MARINONE et al. 2018). Pig farming is one of the main sources of animal protein for human consumption worldwide, especially in South America. According to FAO (2023), global pork production was 119 million tons in 2019, with 8% coming from Latin America and the Caribbean (CPP 2021). The region is home to more than 100 million pigs, distributed mainly across Brazil, Mexico, Chile, Colombia, and Argentina (FAO 2012), and is characterized by its heterogeneity, with intensive and extensive systems presenting varying levels of technology and productivity (GANCHOZO 2022).

However, pork production in South America faces several challenges, both domestically and internationally (BATISTA 2021). These challenges include low productivity, competition with other producing countries, environmental impact, animal welfare, and disease. To overcome these challenges, it is necessary to improve the reproductive efficiency and genetic quality of pig herds, as well as to preserve existing genetic diversity (CONDE 2023). In this regard, reproductive biotechnologies are valuable tools that can contribute to these objectives (UGALDE 2014). These biotechnologies include several techniques that allow the modification of the number, sex, quality, or genetic identity of the offspring (GONZÁLES & GONZÁLES 2005).

Genetic improvement is essential for increasing the competitiveness and sustainability of the swine sector (ITACyL 2020). However, traditional selection and breeding programs have limitations, such as long generation intervals, low selection intensity, high progeny testing costs, and difficulty in measuring complex quantitative traits. In this context, reproductive biotechnologies encompass techniques that manipulate reproductive processes at the cellular or molecular level, with the aim of modifying or controlling fertility, fertilization, embryonic or fetal development, and gene expression (UGALDE 2014, PALMA 2011). These biotechnologies include conventional methods such as artificial insemination (AI) and advanced methods such as embryo transfer (ET), in vitro fertilization (IVF), somatic cloning (SC), and genome editing (GE) (THIEMAN & PALLADINO 2010).

The general objective of this article is to review and analyze the current status and application of the main reproductive biotechnologies in South American pig farming, highlighting advances, challenges, and future perspectives for this sector. To achieve this general objective, the following specific objectives are proposed: evaluate scientific production in reproductive biotechnologies; examine the adoption and application of these technologies in the region; and analyze the perception of publications and the relationships between the dimensions evaluated.

MATERIALS AND METHODS

Sampling strategy and sample size determination.

A sampling strategy was adopted based on a thorough review of the literature on reproductive biotechnologies in pigs in South America (GARCÉS & DUQUE 2007, REYES 2020). The inclusion criteria included articles and theses with experimental results or significant reviews on reproductive biotechnologies, excluding documents that were not relevant or not fully available. A total of 72 articles were selected as a sample, meeting strict inclusion criteria, such as direct relevance to reproductive biotechnologies in swine and full availability of texts.

Each of these 72 documents was evaluated by 18 groups of three students each from the final and penultimate years of the Faculty of Veterinary Medicine and Animal Science (FVMZ) of the National University of Micaela Bastidas de Apurímac, Peru. Each group reviewed four articles, totaling 72 reviews. The sampling formula for proportions used was $n = (Z^\wedge 2 * p * q)/E^\wedge 2$ where p=0.5 (estimated proportion), Z=1.96 (95% confidence level) and E=0.1155. Although the ideal calculation suggested a larger sample size, the limited availability of relevant studies justified the use of 72 articles, ensuring a focused and relevant analysis.

Materials Used

To collect information, several scientific databases were used, such as Scopus, Web of Science, Redalyc, SciELO, and institutional repositories, in addition to consulting reports and publications from international organizations on pig farming in South America. The measuring instrument was divided into two main variables: 1. Current Impact of Reproductive Biotechnologies, including the dimensions of regional impact, clarity, and coverage; and 2. Future Perspectives and Technological Development, which encompasses the dimensions of technological advances, future perspectives, and the identification of challenges. Each dimension was assessed using a Likert scale ranging from 1 to 5, where 1 represents the lowest and 5 represents the highest. This scale allowed us to evaluate aspects such as the impact of the article on the region, the clarity of the text, the scope of biotechnological methods, and the relevance of technological advances and future challenges. This structure facilitated a detailed and differentiated evaluation of the main aspects of publications in the field of reproductive biotechnologies. It is worth noting that the instrument demonstrated 70.1% reliability according to the Cronbach's alpha test.

Data collection

To collect data, Google searches were performed using keywords related to reproductive biotechnologies in pigs. Recognized scientific databases, such as Scopus, Web of Science, Redalyc, SciELO, and institutional repositories, were consulted in Spanish, English, and Portuguese. This methodology allowed the selection of relevant articles and ensured adequate topic coverage.

Data processing and analysis

The collected data were managed and analyzed using SPSS and Excel. Descriptive statistics were applied to calculate frequencies and medians, providing a clear view of the distribution and central tendency of the responses. To identify relationships between the different dimensions evaluated, Multiple Correspondence Analysis (MCA) was used.

RESULTS

Distribution of publications on reproductive biotechnology in swine in South America (2018-2024)

We evaluated 72 publications on reproductive biotechnology in swine. As illustrated in figure 1, the countries with the highest scientific production between 2018 and 2024 were Brazil (22 publications), Argentina (16), Ecuador (13), Peru (10), Colombia (7), Bolivia (3), and Uruguay (1). The most discussed topics were artificial insemination (AI - 41 mentions), in vitro fertilization (IVF - 17), genome editing (EG - 10), embryo transfer (ET - 3) and somatic cloning (SC - 1), as shown in Table 1.

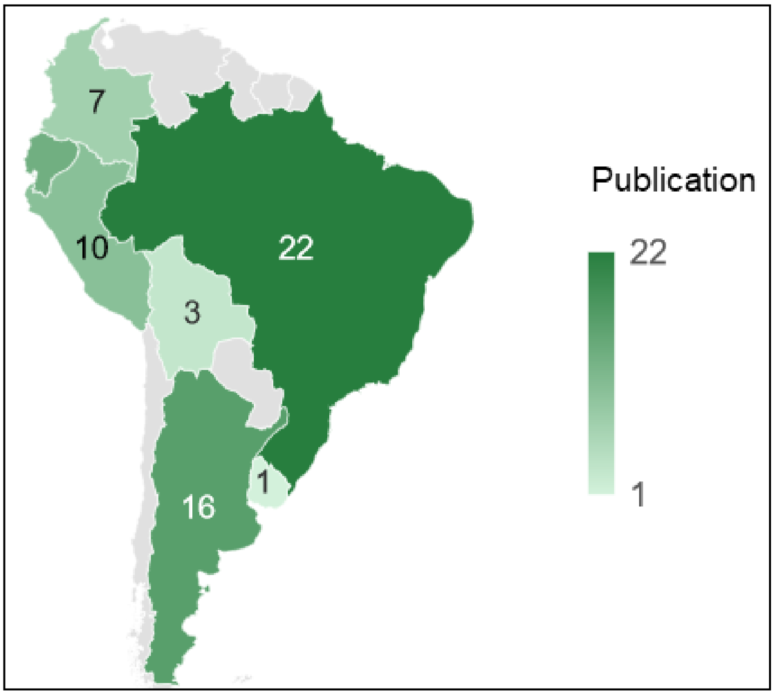

Figure 1. Reproductive Biotechnologies in South American Swine from 2018 to 2024.

Table 1. The types of reproductive biotechnology applied to swine by country in South America (2018-2024).

Country	Biotechnology					Total
	AI	ET	IVF	SC	GE	
Brazil	9	1	9	0	3	22
Argentina	5	1	6	1	3	16
Ecuador	13	0	0	0	0	13
Peru	7	0	1	0	2	10
Colombia	4	1	1	0	1	7
Bolivia	3	0	0	0	0	3
Uruguay	0	0	0	0	1	1
Total	41	3	17	1	10	72

Impact, future perspectives, and technological development of reproductive biotechnologies

The analysis reveals an increase in the adoption of reproductive biotechnologies, driven by the need to increase productivity and address environmental and health challenges. Artificial insemination is the most widely used technique because of its simplicity and cost-effectiveness. Overcoming technical and economic barriers to embryo transfer and in vitro fertilization can improve the competitiveness and sustainability of the pork sector in South America. The evaluation shows that the articles studied (Figure 2) are generally perceived as being of high quality in all dimensions examined, with a median of "4" in Technological Advances, Identification of Challenges, Future Perspectives, Impact on South American Pig Farming, Clarity and Comprehensibility, and Coverage of Conventional and Advanced Methods. This indicates that, in general, FVMZ students consider these aspects noteworthy. The mode is also 4 in most categories, except for Impact on South American Pig Farming, where it is 3, suggesting that the high level is assigned more frequently, although with some uncertainty or variability in this specific area. Standard deviations, ranging from 0.702 to 0.835, indicate that responses are clustered around the median, indicating a consensus in the assessment of categories. However, the larger standard deviations in the identification of challenges and impacts on SAF suggest greater diversity in the perceptions of these aspects, possibly due to differences in the interpretation of challenges and impacts.

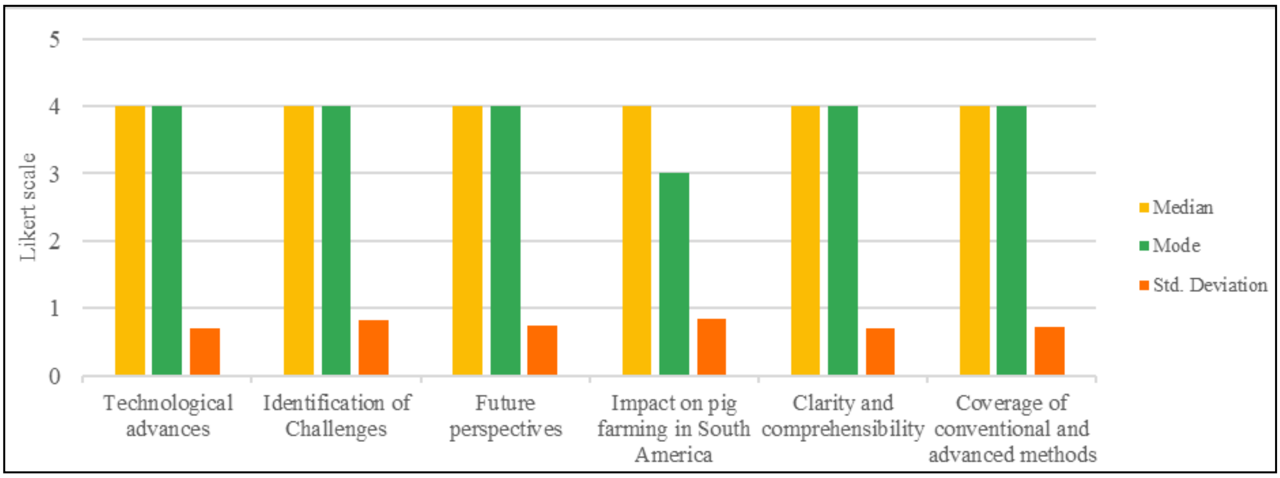

Figure 2. Assessment of the quality of publications on reproductive biotechnologies in swine in South America according to key dimensions.

The results of the Multiple Correspondence Analysis (MCA) show a strong relationship between the dimensions "Technological Advances", "Challenge Identification" and "Coverage of Conventional and Advanced Methods", with correlations close to 1 (Figure 3). This indicates that articles describing technological innovations tend to comprehensively address biotechnological methods and identify relevant challenges in the field. On the other hand, the dimensions "Future Perspectives" and "Clarity and Comprehensibility" show lower correlations with these dimensions, suggesting that they are not so closely related to technological innovations or the scope of methods in the reviewed articles. The eigenvalues indicate that Dimension 1 explains most of the variability in the data, followed by Dimensions 2 and 3, which are also significant but less dominant. These findings highlight the importance of technological innovation and detailed coverage of methods in terms of the quality and impact of publications in reproductive biotechnology, while future perspectives and clarity do not seem to be as decisive in this dimension of the analysis.

Multiple Correspondence Analysis (MCA) summarized in Table 2 reveals the relationships between various reproductive biotechnologies and key aspects of perception. Artificial Insemination (AI) presents a very high correlation with technological advances and method coverage, reflecting a high perception of these methods as being advanced and well-covered, with correlations of 0.998 and 0.996, respectively. According to our data, AI is considered an advanced technology with broad acceptance and recognition in terms of challenges and coverage. In contrast, Embryo Transfer (ET) demonstrated low correlations in these aspects, indicating a lower perception of progress and coverage, with values of 0.082 and 0.103. In vitro fertilization (IVF) is positioned in an intermediate range, with moderate correlations of 0.195 with technological advances and 0.103 with coverage, and a moderate positive perception of its impact on pig farming (0.322). Somatic Cloning (SC), although perceived as technologically advanced with a high correlation of 3.518 in dimension 2, presents low frequency of use and coverage, with correlations of 0.193 and 0.103. Finally, Genome Editing

(GE) also presents moderate correlations with technological advances (0.265) and method coverage (0.103), indicating that, although considered advanced, it does not enjoy the same level of acceptance as AI.

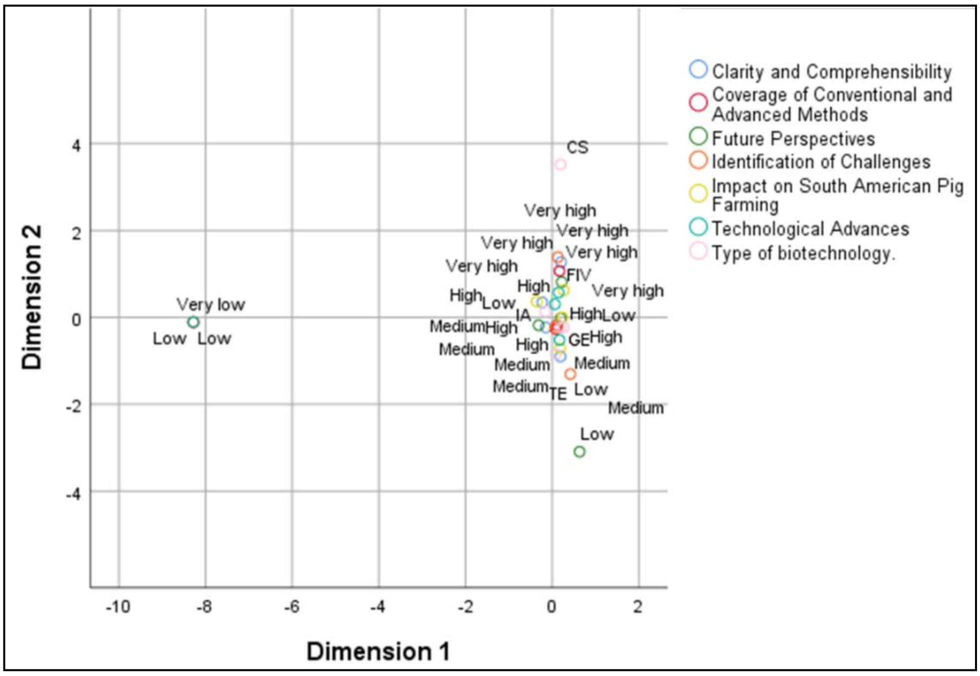

Figure 3. Multiple Correspondence Analysis of Variables Related to Reproductive Biotechnologies in South America.

Table 2. Relationship between reproductive biotechnologies and technological advances, challenges, impact, and scope: results of Multiple Correspondence Analysis (MCA).

Biotechnology	Technological Advances	Identifying Challenges	Future Perspectives	Impact on Swine Farming	Clarity and Understanding	Conventional and Advanced Methods
Artificial insemination (AI)	0.998	0.996	0.145	0.165	0.100	0.998
Embryo Transfer (ET)	0.082	0.115	0.154	0.164	0.103	0.103
In Vitro Fertilization (IVF)	0.195	0.061	0.322	0.152	0.070	0.113
Somatic Cloning (SC)	0.193	0.130	0.220	0.265	0.206	0.171
Genome Editing (GE)	0.265	0.116	0.220	0.079	0.070	0.265

In Figure 4, the discriminant measures of the Multiple Correspondence Analysis (MCA) variables, Dimension 1, which explains 44.54% of the total variance, are dominated by the variables "Technological Advances" (weight 0.969) and "Coverage of Conventional and Advanced Methods" (weight 0.967), indicating that these variables have a high contribution to the explanation of this dimension, with averages of 0.581 and 0.598, respectively. This suggests that perceptions of technological sophistication and method coverage are crucial for dimension 1. In contrast, Dimension 2, which accounts for 32.05% of the variance, is mainly influenced by "Challenge Identification" (weight 0.972) and "Clarity and Understandability" (weight 0.572), with a notable average of 0.710 for the first variable, reflecting its relevance in explaining this dimension. The variable "Future Perspectives" (weight 0.070) has a low weight in Dimension 1, with equally low averages, suggesting a lower influence on the overall perception of this dimension.

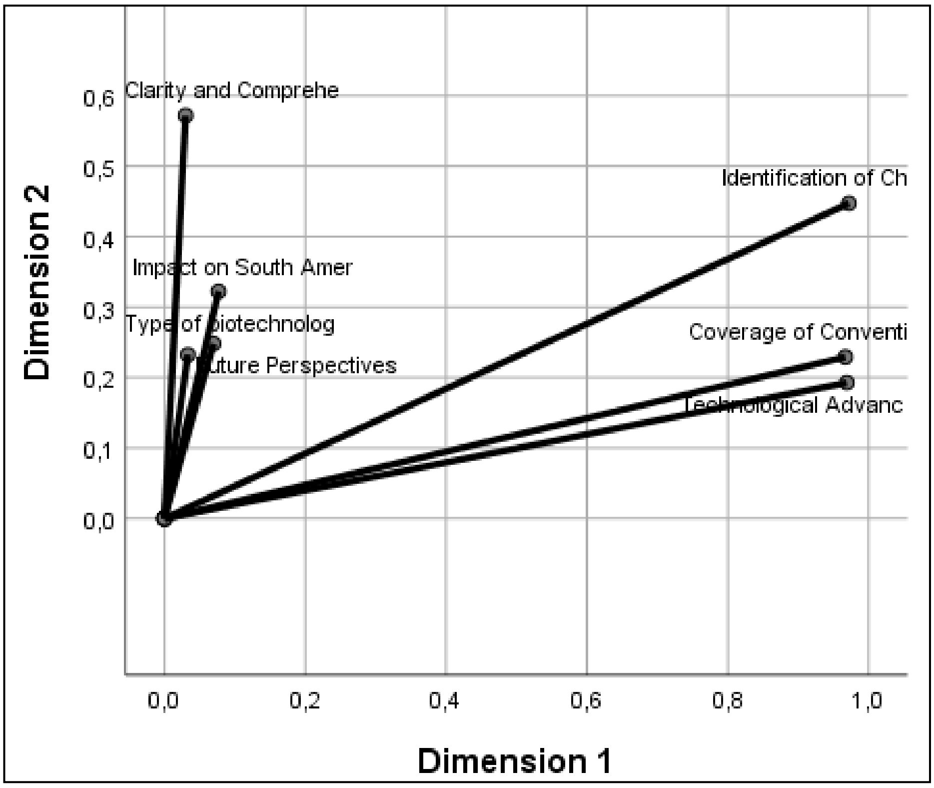

Figure 4. Discriminant measures of variables in Multiple Correspondence Analysis (MCA): influence of key variables on dimensions

DISCUSSION

In South America, the use of reproductive biotechnologies in pig farming has increased significantly in recent years, driven by the growing demand for pork and the need to adapt production to regional environmental and health conditions (UGALDE 2014, BISANG & CESA 2009). This discussion synthesizes the main findings and applications of each biotechnology in pig farming in the region.

Artificial Insemination (AI): AI is the most widely used technique globally and regionally. This technique involves depositing the male's semen into the female's reproductive tract without the need for direct physical contact (VANINA et al. 2019). AI offers multiple benefits, including an increase in the number of offspring per male, better genetic distribution, reduced risk of disease transmission, and optimization of reproductive management (TORRENTES et al. 2013). AI can be performed using fresh, chilled, or frozen semen. Fresh semen is used immediately after collection; refrigerated semen is stored at temperatures between 15°C and 18 °C with diluents that preserve sperm viability (ROSSI 2012); frozen semen undergoes cryopreservation at 196°C with liquid nitrogen, allowing indefinite storage and long-distance transportation, although it requires specialized infrastructure (CAZALES et al. 2020).

Advances in AI have focused on improving semen quality and preservation (RODRÍGUEZ 2020), as well as on developing estrus and ovulation synchronization protocols to facilitate timed artificial insemination (TAI) (FLORES 2022). Current methods for assessing semen quality include computerized analysis of sperm motility, flow cytometry, fluorescent staining techniques, and functional tests (CARVAJAL 2018). Semen preservation is improved through the use of commercial or natural diluents, temperature and storage time control, addition of antioxidants or antibiotics, and cryopreservation (TORRES et al. 2019). TAI uses hormonal protocols to synchronize estrus and ovulation, based on exogenous gonadotropins, GnRH analogs, or prostaglandins (ALONSO et al. 2007). This technique allows for simplified reproductive management, reduction of the weaning-estrus interval, increase in the number of annual births, and better litter uniformity (PÉREZ et al. 2022).

AI can be performed on the cervix or uterus. Cervical insemination involves inserting the catheter into the cervix and depositing semen inside it, whereas uterine insemination involves advancing the catheter beyond the cervix and depositing semen in the uterine horn (SUÁREZ et al. 2022). Uterine insemination allows the use of reduced doses of semen and sexed semen, which is separated by flow cytometry to select spermatozoa carrying the X or Y chromosome (TORRENTES et al. 2013, SUÁREZ et al. 2022). Although AI has proven to be effective and cost effective, with application in more than 90% of commercial farms and more than 50% of family farms (ALVARADO 2018), its adoption faces limitations such as a lack of personnel training, low semen quality, adverse environmental conditions, reproductive diseases, and logistical issues (ROCHA 2005).

Embryo Transfer (ET): ET involves collecting embryos from a donor female and transferring them to the uterus of a recipient female, with prior synchronization of their reproductive cycles (VEGA 2021). This technique allows for an increase in the number of descendants per female, preservation and dissemination of superior genetics, facilitation of genetic exchange between regions, creation of embryo banks, and conservation of breeds threatened with extinction (CABRERA & FERNANDEZ 2006). ET optimizes the genetic potential of high-value females and can improve animal welfare. However, this approach presents challenges such as low embryo recovery rates, difficulty in synchronizing cycles, and the need for surgical procedures for embryo implantation (BARRALES et al. 2021). The additional advantages of ET and other reproductive biotechnologies include the preservation of native breeds, the introduction of disease-resistant genes, the improvement of animal welfare, the reduction of production costs, and the optimization of genetic resources (RODRÍGUEZ et al. 2011). However, challenges remain, including the low efficiency of the techniques, the lack of infrastructure and trained personnel, and ethical, legal, and environmental impacts. It is essential to conduct more research, develop specific protocols for each situation and promote cooperation between the public and private sectors, as well as between countries in the region. The main challenges in ET include improving the efficiency and practicality of embryo collection and transfer techniques and increasing the availability and quality of embryos (SALGADO & LOPERA 2020). Embryo collection methods include laparotomy, laparoscopy, and transcervical catheterization, whereas transfer techniques involve surgery, endoscopy, and transcervical catheterization. Embryo preservation is achieved by refrigeration and cryopreservation (CABRERA & FERNÁNDEZ 2006, HERNÁNDEZ et al. 2018). Although TE has been successfully applied to embryos in vivo and in vitro, its commercial use remains limited because of high costs.

In vitro fertilization (IVF): IVF is a crucial biotechnology that involves combining eggs and sperm in a laboratory to create embryos, which are then transferred to a surrogate uterus where they are implanted and develop. IVF offers significant advantages over traditional reproduction, including greater reproductive efficiency by increasing the number of piglets born per sow, reduced production costs, and better utilization of high-quality sows (MONTES 2004). Additionally, IVF contributes to greater genetic diversity in the pig population, improves meat quality, reduces the risk of disease, and optimizes meat production (VILLARROEL 2023). This biotechnology is increasingly used in South American pig farming, and it is essential for improving reproductive efficiency and meat production in the region.

Adoption and application of technologies: Artificial insemination (AI) has emerged as the most prevalent reproductive biotechnology, and is known for its high adoption rate in commercial operations. However, its penetration in family farming remains low. Advances in semen quality and synchronization protocols have optimized the use of semen. On the other hand, in vitro fertilization (IVF), despite its high potential, faces significant barriers because of its high cost and the need for advanced infrastructure. Embryo transfer (ET) offers advantages in the rapid multiplication of genetic material, but its application is limited to smaller operations because of economic and operational reasons. Somatic cloning (SC) and gene editing (GE) have high potential for genetic improvement, but their adoption is restricted by high costs and ethical issues, limiting their widespread use in commercial production.

Perception of publications and relationships between dimensions: Analysis of publications using a Likert scale and Multiple Correspondence Analysis (MCA) shows that publications in reproductive biotechnologies are perceived as being of high quality in dimensions such as technological advances and methods coverage, while perceptions about "Future Perspectives" and "Clarity and Comprehensibility" are less prominent. The strong correlation between technological advances, identification of challenges, and coverage of conventional and advanced methods indicates that articles presenting innovations tend to fully address these aspects. However, future prospects and clarity are not as closely linked to technological innovations, suggesting that although publications are seen as advanced, discussions about their future impact and presentation could be improved.

CONCLUSION

In South America, the adoption and application of reproductive biotechnologies in pig farming have experienced significant growth in recent years. Techniques such as artificial insemination, embryo transfer, and in vitro fertilization are fundamental for improving reproductive efficiency, increasing production, and optimizing genetic resources. Despite these advances, challenges related to infrastructure, personnel training, and ethical and environmental aspects persist. It is essential to continue conducting research and developing specific protocols for each technique, as well as to promote greater cooperation between the public and private sector to overcome current limitations.

In recent years, scientific production in reproductive biotechnologies has been significantly increasing. However, an analysis of publication insights revealed that only 45% of research focuses on advanced techniques such as in vitro fertilization and somatic cloning. This disparity indicates the need for more applied research and development in less-covered areas.

Artificial insemination (AI) is used on more than 90% of commercial farms, demonstrating its high adoption and effectiveness in the region. In contrast, embryo transfer (ET) and in vitro fertilization (IVF) have limited adoption, with only 10% of farms applying these technologies because of challenges such as high costs and low efficiency. This suggests that more accessible and cost-effective protocols need to be developed to improve implementation.

Multiple Correspondence Analysis (MCA) revealed that 55% of scientific publications highlight advances in AI and ET, whereas only 25% address IVF. The perception of the quality and coverage of these technologies show that 70% of respondents consider AI information to be clear and understandable, whereas 40% of respondents feel the same about IVF. These findings suggest the need to improve the quality of information available on advanced techniques to facilitate better adoption and application in the swine sector.

REFERENCES

CPP. 2021. Comunidad Profesional Porcina. Resumen de la evolución del mercado mundial de carne de cerdo en 2020. Girona: *3tres3*. Disponível em: https://www.3tres3.com/latam/ultima-hora/fao-evolucion-del-mercado-mundial-de-carne-de-cerdo-en-2020_13128/

FAO. 2012. Organización De Las Naciones Unidas Para La Alimentación y la Agricultura. Buenas Prácticas Pecuarias (BPP) para la producción y comercialización porcina familiar. Salud Animal. Buenos Aires: FAO. 277.

FAO. 2023. Organización De Las Naciones Unidas Para La Alimentación y la Agricultura. Perspectivas Agrícolas 2023 – 2032. Paris: FAO. 289.

ITACyL. 2020. Instituto Tecnológico Agrario de Castilla y León. Mejora de la tecnología de la producción y reproducción porcina-TECNIPORC. Castilla y León. ITACyL. Disponível em: https://www.itacyl.es/investigacion-e-innovacion/i-i-ganadera/genetica-y-reproduccion-animal/-/asset_publisher/OXguUicwVLum/content/mejora-de-la-tecnologia-de-la-produccion-y-reproduccion-porci-1

ALONSO et al. 2007. Evaluación de Cuatro Protocolos de Sincronización Para Inseminación a Tiempo Fijo en Vacas Bos indicus Lactantes. Rev Cient 17: 501-507.

ALVARADO W. 2018. Caracterización de la crianza de cerdos de traspatio en la provincia de Chachapoyas, Amazonas, Perú. Tesis de posgrado. Chachapoyas: UNTRM. 88p.

BARRALES H et al. 2021. Manual de producción porcina. Cadena de valor de la producción sustentable en Argentina. La Plata: Universidad Nacional de la Platta. 225p.

BATISTA L. 2021. Retos de la porcicultura latinoamericana. Rev Rev Porc Latam 2: 1-6.

BISANG R & CESA V. 2009. Biotecnología y desarrollo. Santiago de Chile: Naciones Unidas. Disponível em: http://repositorio.cepal.org/bitstream/handle/11362/3650/1/S2009064_es.pdf%0Ahttp://uniciencia.ambientalex.info/infoCT/Biodesint.pdf

CABRERA P & FERNÁNDEZ A. 2006. Criopreservación de embriones: una herramienta básica en la reproducción asistida. Rev Fac Cienc Vet 47: 59-70.

CARVAJAL M et al. 2018. Evaluación de los parámetros de calidad seminal y cinemática espermática en tres razas ovinas de lana en condiciones de trópico alto colombiano. Rev Med Vet 11: 49-61.

CAZALES N et al. 2020. Inseminación artificial con semen congelado equino: reacción inflamatoria, transporte espermático y técnica de inseminación. Veterinaria 56: 1–8.

CONDE R. 2023. La genética porcina: características e importancia económica. Veterinaria Digit. 1: 1-3.

CÓRDOVA A et al. 2022. Las biotecnologías reproductivas en la mejora de la seguridad alimentaria. Veterinaria Digit 2: 1–3.

FLORES J. 2022. Evolución de las tecnologías de reproducción asistida. Una mirada desde la biomedicina. Interdisciplina 10: 355 - 368.

GANCHOZO M. 2022. Caracterización de los sistemas de producción porcina en el cantón Bolívar. Tesis (Médico Veterinairo). Calceta. ESPAMMFL. 86p.

GARCÉS J & DUQUE E. 2007. Metodología para el análisis y la revisión crítica de artículos de investigación. Innovar 17: 184–94.

GONZÁLES H & GONZÁLES H. 2005. Biotecnología Reproductiva: Una Alternativa Para Mejorar La Producción Animal. Biotempo 5: 5–11.

HERNÁNDEZ M et al. 2018. Aspiración de ovocitos por laparoscopía para la transferencia de embriones en cabras: una revisión. Abanico veterinario 8: 14-23.

MARINONE A et al. 2018. Biotécnicas reproductivas en la especie porcina: Pasado, presente y futuro. Rev Investig Agropecu 44: 25–38.

MONTES G. 2004. Bioética y técnicas de reproducción asistida. Rev. cienc. adm. financ. segur. soc 12: 71-78.

PALMA G. 2011. Biotecnología de la reproducción. Argentina: INTA. pag.701.
PÉREZ E et al. 2022. Función ovárica y respuesta a la sincronización del estro en ganado Criollo en México. Revisión. Rev Mex Ciencias Pecu 13: 422–51.
RENTERÍA J et al. 2021. Principales aportes de la investigación del INIFAP a la nutrición porcina en México: retos y perspectivas. Rev Mex Ciencias Pecu 12: 79 - 110.
REYES H. 2020. Artículos de Revisión. Rev Med Chil. 148: 103–108.
ROCHA G. 2005. Factores que afectan la producción de dosis de semen en centros de inseminación artificial porcina. Rev AIA. 9: 33-43.
RODRÍGUEZ M et al. 2011. Biotecnologías reproductivas aplicadas a la mejora genética animal. Cangue 31: 44-50.
RODRÍGUEZ E. 2020. Evaluación de dos diluyentes alternativos para la preservación de semen porcino refrigerado en el trópico bajo colombiano. Tesis de Ingeniero Pecuario. San José de Cucuta: UFPS. 77p
ROSETE J et al. 2021. Biotecnologías reproductivas en el ganado bovino: cinco décadas de investigación en México. Rev Mex Cienc Pecu 12: 39-78.
ROSSI A. 2012. Efecto de la refrigeración y la adición de trehalosa en los parámetros de viabilidad microscópicos de semen bovino. Tesis (Ingeniero en producción agropecuaria). Buenos Aires: UCA. 66p.
SALGADO E & LOPERA R. 2020. Aspectos esenciales sobre las técnicas de fertilización in vitro en bovinos. Rev Inv Vet Perú 31: e17138.
SUÁREZ A et al. 2022. Evaluación de la inseminación artificial post cervical vs cervical en Ios parámetros productivos. Rev Rev Porc Latam.
THIEMAN W & PALLADINO M. 2010. Introducción a la Biotecnología. 2.ed. Madrid: Pearson Educacion SA. pag. 406.
TORRENTES R et al. 2013. Manual de inseminación artificial porcina. Managua: Universidad Nacional Agraria. 87p.
TORRES F et al. 2019. Efecto de la adición de antioxidantes en los diluyentes para la preservación de semen ovino. Rev Med Vet. 1: 1-9.
UGALDE J. 2014. Biotecnologías reproductivas para el siglo XXI. Revista Cubana de Ciencia Agrícola 48: 33-34.
VANINA M et al. 2019. Inseminación Artificial en la especie porcina: dosis inseminante en relación al lugar de deposición. Analecta 39: 1-19.
VEGA F. 2021. Biotecnología embrionaria: Transferencia de embriones en ganado vacuno. Tesis (Médico Veterinario). Santiago de compostela: USC. 49p.
VILLARROEL E. 2023. Identificación de factores humanos para conseguir la preñez de cerdas inseminadas artificialmente. La Calera 23: 67-76.