

Worldwide scientometric production on selenium, vitamin E, and reproductive outcomes in goats, sheep, and cattle

Producción cienciométrica mundial sobre selenio, vitamina E, y resultados reproductivos en caprinos, ovinos y bovinos

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ABSTRACT. Ruminants represent a fundamental component for animal production and food security; among them, goats stand out for their resilience in marginal ecosystems. However, factors such as heat and nutritional stress in arid lands induce oxidative stress, compromising reproductive outcomes such as oocyte viability and embryo implantation. Therefore, selenium (Se) and vitamin E (VitE) emerge as components of the antioxidant defense system. Se acts as a cofactor for enzymes that neutralize peroxides, and VitE optimizes follicular maturation and embryonic development. Deficiencies in these factors can lead to reproductive failure, ranging from anovulation to fetal death. The implementation of scientometric strategies allows for a critical analysis of the evolution of knowledge in this area. Through scientific mapping, the main approaches, authors, journals, and countries in this field of study can be identified. We carried out a study according to the PRISMA methodological guidelines, applying a rigorous protocol for search, selection, and analysis. The analysis includes scientific output (2000-2025), denoting an increase in publications from 2010 onward, as well as a notable disproportion in the number of studies focused on other livestock species compared to goats. This quantitative analysis identified trends and gaps, including a reduced co-authorship network density and a limited number of goat-specific publications. Therefore, scientometric documents are generated and act as an essential diagnostic tool to guide the funding and design of future research focused on mitigating the environmental impact on the reproductive efficiency of goats.

Keywords: Bibliometrics, VOSviewer, reproduction, oxidative stress, livestock.

RESUMEN. Los rumiantes representan un componente fundamental para la producción animal y la seguridad alimentaria, entre ellos destacan las cabras por su resiliencia en ecosistemas marginales. Sin embargo, factores como el calor y el estrés nutricional en zonas áridas inducen estrés oxidativo que compromete el rendimiento reproductivo como la viabilidad de los ovocitos y la implantación del embrión. El selenio (Se) y la vitamina E (VitE) emergen como componentes del sistema de defensa antioxidante; Se actúa como cofactor de enzimas que neutralizan los peróxidos y la VitE optimiza la maduración folicular y el desarrollo embrionario. Alguna deficiencia de estos provoca un fallo reproductivo, desde anovulación hasta mortalidad fetal. La implementación de estrategias cienciométricas permite un análisis crítico de la evolución del conocimiento en esta área. Mediante el mapeo científico, se identificaron los principales enfoques, autores, revistas y países en este campo de estudio. Se desarrolló un estudio con base en las directrices metodológicas del modelo PRISMA, con la aplicación de un protocolo riguroso de búsqueda, selección y análisis. El análisis abarcó la producción científica (2000-2025) denotando un incremento en las publicaciones a partir de 2010, así como una notable desproporción en el número de estudios centrados en otras especies ganaderas en comparación con las cabras. Este análisis cuantitativo y cualitativo identificó tendencias y deficiencias, incluyendo una menor densidad de redes de coautoría y un número limitado de publicaciones específicas sobre cabras. Por ello, esta estrategia cienciométrica documenta la producción científica y actúa como una herramienta de diagnóstico esencial para orientar la financiación y el diseño de futuras investigaciones centradas en mitigar el impacto ambiental en la eficiencia reproductiva de las cabras.

Palabras clave: Bibliometría, VOSviewer, reproducción, estrés oxidativo, ganado.

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INTRODUCTION

Animal production plays an essential role in sustaining populations and in global food security (Wodajo *et al.* 2020). In particular, ruminants represent a key component of livestock systems due to their ability to transform fibrous resources and forages unsuitable for human consumption into products of high nutritional value, such as meat and milk (Davis and White 2020). Among them, goats have acquired special importance due to their adaptability and their historical contribution to human development; since their domestication, they have been recognized as a species of global relevance (Meza-Herrera *et al.* 2024). Their products continue to impact society by offering nutritional, economic, and environmental sustainability (Navarrete-Molina *et al.* 2020, Meza-Herrera *et al.* 2022, Lu 2023), particularly in marginal production systems (Navarrete-Molina *et al.* 2024). The versatility of goats has allowed them to adapt to various conditions and climates, particularly in arid lands (Gonzalez-Bulnes *et al.* 2011, Meza-Herrera and Tena-Sempere 2012, Daramola *et al.* 2021). However, this ecotype entails seasonal variability in the quality and quantity of feed, causing nutritional and thermal stress, compromising the productive and reproductive performance of goats (Urrutia-Morales *et al.* 2009, Meza-Herrera *et al.* 2010, Meza-Herrera *et al.* 2015, Sa'ayinzat *et al.* 2021). Therefore, an adequate supply of vitamins and minerals is central to increasing reproductive outcomes (Kaya *et al.* 2023). Similarly, antioxidants, present in certain vitamins and minerals, reduce the harmful effects generated by oxidative stress. Moreover, excessive production of reactive oxygen species (ROS) and nitrogen reactive species (RNS) compromises not only oocyte viability but also limits embryo implantation (Rakha *et al.* 2022, Mora *et al.* 2019).

Selenium (Se) is an antioxidant micromineral that catalyzes the reduction of peroxides and lipoperoxides generated during diverse physiologic processes, such as pregnancy; it also suppresses the induction of pro-inflammatory cytokines (Pieczyńska *et al.* 2024). Therefore, low or no ovulation, embryo loss, and stillbirth can be triggered. Vitamin E (VitE) improves the ovulation rate and the number of offspring by promoting oocyte maturation, fertilization, and embryonic implantation and development (Özar *et al.* 2022, Santos-Silva *et al.* 2025). Therefore, it is important to identify trends on this topic and find information gaps to have a descriptive and interpretative panorama, being critical to build scientific questions (Arbeláez and Onrubia 2014). Scientometrics is a quantitative analysis method that examines the production and evolution of global scientific literature in a given area of knowledge to identify research trends, analyze the productivity of authors and institutions, and generate evidence to support research decision-making and funding processes (Michán and Muñoz-Velasco 2013). We hypothesize that scientific production on the use of antioxidant supplements such as selenium and/or vitamin E in reproduction, specifically in ovulation rate and implantation rate, is limited in goats compared to other animal species. Likewise, those countries that contribute the most to this research topic have not only higher levels of development but also face recurrent thermal insults. This study aimed to analyze the results of research published in three scientific platforms, regarding the effect of supplementation with Se and VitE and its possible relationship with the ovulatory rate and embryo implantation of goats during the period 2000-2025.

MATERIALS AND METHODS

The scientometric analysis considered the PRISMA method (Figure 1) criteria for identifying, selecting, evaluating, and synthesizing studies (Page *et al.* 2021) as well as the methodology proposed by Michán and Muñoz-Velazco (2013); briefly, it considers the following steps:

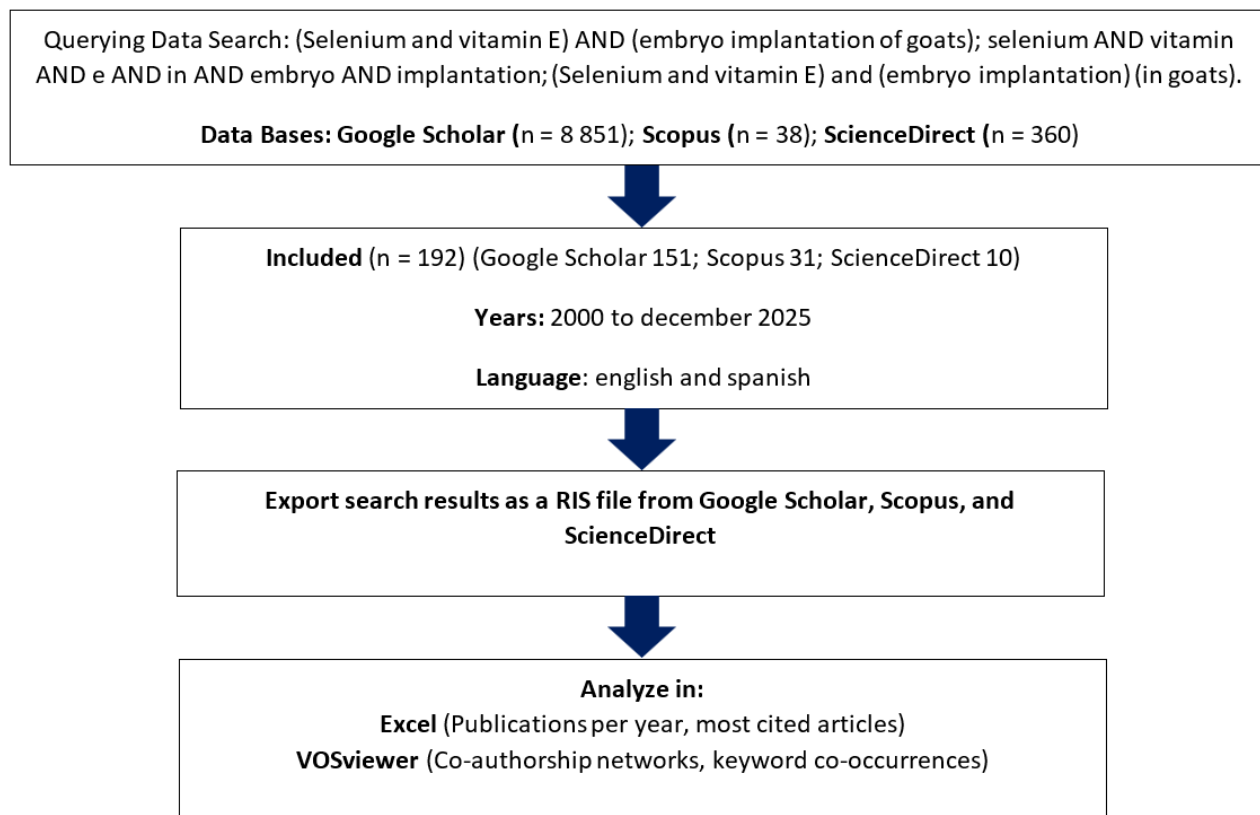


Figure 1. Information collection and processing flowchart.

Retrieval and search strategy

The sources of information to be used to establish the search for scientific articles with optimal terms, operators, and criteria were selected; the bibliographic tools Google Scholar, Scopus, and ScienceDirect were used. The systematic search considered that they addressed the use of SE and VitE in embryo implantation, and considered books, theses and scientific articles from the selected period, using the operators: (Selenium and vitamin E) AND (embryo implantation of goats); selenium AND vitamin AND e AND in AND embryo AND implantation; (Selenium and vitamin E) and (embryo implantation) (in goats).

Inclusion and exclusion criteria

Once the database was formed, inclusion and exclusion criteria were considered, including only scientific articles, review articles, books, and book chapters published in English and Spanish that addressed the topic of interest in the disciplinary field of animal or veterinary production, which

were aligned with the keywords entered in the search (Romero and Camarena 2023), excluding duplicate documents.

Migration

It considered downloading the corpus of searches in Google Scholar, Scopus, and ScienceDirect in the standardized RIS (Research Information Systems Incorporated) format. The selected information was incorporated into a new database, and a filtering process was carried out to obtain normalized data.

Analysis, visualization, and interpretation

The analysis, visualization, and bibliographic mapping of the results were performed using VOSviewer 1.6 software, a robust and widely recognized tool for bibliometric analysis. Subsequently, a clustering algorithm was run to position and classify the keywords and to show bibliographic coupling among countries, the collaboration among authors, and keyword co-occurrence (Hernández-García *et al.* 2024). Finally, the results obtained were interpreted as previously proposed (Cardona-Román and Sánchez-Torres 2017).

RESULTS

In the period analyzed (2000 – 2025), a total of 192 publications related to the topic of study (Se, VitE, OT, and IE) were identified; 151 documents in Google Scholar, 31 scientific articles in Scopus, and 10 documents in ScienceDirect (Figure 2). Most publications were review articles ($n = 87$), followed by original articles ($n = 86$), then book chapters ($n = 18$), and books ($n = 1$). From the beginning of the search in the year 2000, the annual average of published scientific documents was 7.38 (Figure 2). From 2010 onwards, a sustained growth began with its peak in 2025 (39 publications). The period 2020–2025 accounted for 58% (112 publications) of the total number of documents, suggesting a growing and recent interest in the subject.

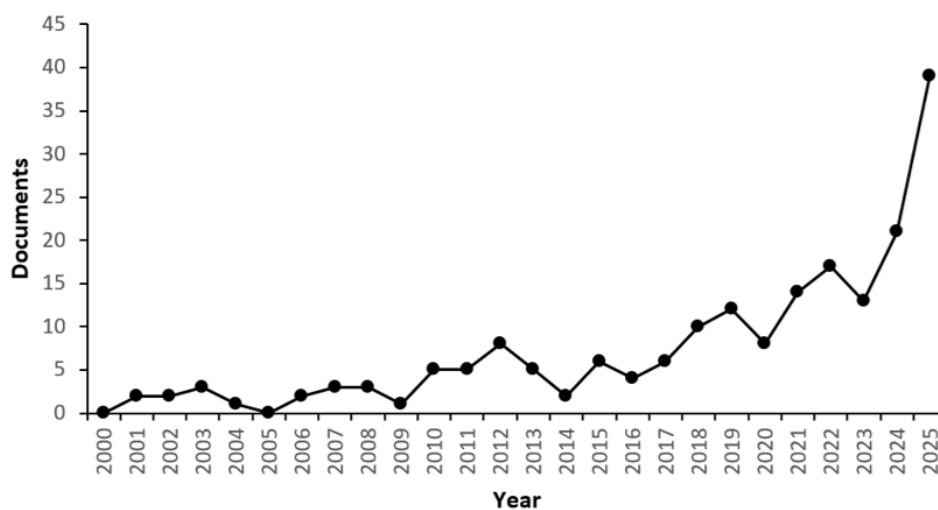


Figure 2. Annual evolution of scientific publications on selenium and/or vitamin E in reproduction of mammals during 2000-2025.

Although only 14 documents focused specifically on goats, the remaining studies were not excluded from the analysis because most of them addressed ruminants, while others focused on mammals in general and included explicit references to goats as part of their content (Figure 3).

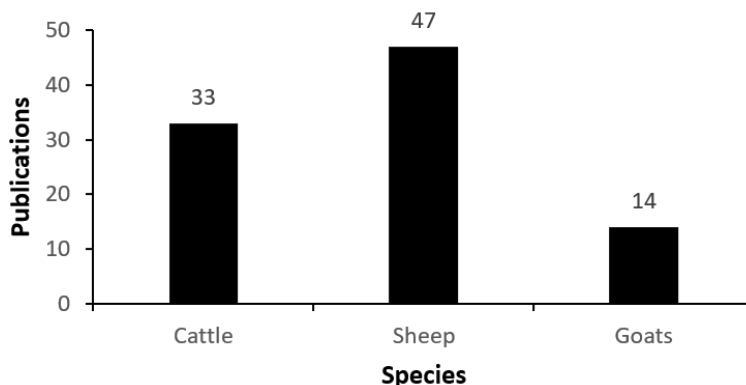


Figure 3. Distribution of scientific production on selenium and/or vitamin E in cattle, sheep, and goats from 2000 to 2025.

Table 1 presents the most influential publications addressing the effects of selenium and/or vitamin E on reproductive processes, as well as studies examining oxidative stress, a critical factor affecting animal reproductive performance. The data analyzed in Table 1 were obtained exclusively from the Scopus database, as this platform is a reliable data source that allows users to access and download the complete metadata for each publication, in addition to providing the actual number of citations at the time the data were retrieved. Moreover, the Google Scholar and ScienceDirect platforms were used solely to estimate the total number of scientific publications produced during the study period (2000–2025). Among these contributions, the article entitled “Oxidative Stress and Antioxidants: Exposure and Impact on Female Fertility” stands out as the most highly cited publication, accumulating 290 citations. This is followed by the article “Oviduct: Roles in Fertilization and Early Embryo Development,” which has received 230 citations. The high citation frequency of these studies highlights the growing scientific interest in understanding the relationship between oxidative balance, antioxidant supplementation, and reproductive efficiency.

Table 2 shows the journals that publish the most research manuscripts related to antioxidant supplementation, such as selenium and/or vitamin E, with special emphasis on animal reproduction, as well as their related characteristics, including impact factor and quartile up to January 2026. Besides, a total of 145 journals were identified, of which the one that tops the list is the journal *Tropical Animal Health and Production*, with five documents (3.44%) with an impact factor of 1.7. Interestingly, 113 journals published only one article (77.9%). It is noteworthy that, from the top-10 journals, 8 of them are published in Europe: Switzerland leads (3), followed by the Netherlands (2), the United Kingdom (2), and Germany (1). The other two countries belong to the American continent: Mexico and the United States, each with 1 journal.

Regarding the number of articles published by such journals, Switzerland leads with 9 publications, followed by the United Kingdom with 8 publications, the Netherlands with 5, and Germany with 3. In the Americas, the United States leads with 3 publications and Mexico with 2 publications.

Table 1. Most cited articles related to the use of selenium and/or vitamin E in reproduction from 2000 to 2025.

Rank	Title	Citations	Authors	Journals	Year	Type	DOI
1	Oxidative stress and antioxidants: Exposure and impact on female fertility	290	Ruder <i>et al.</i>	Human Reproduction Update	2008	Article	10.1093/humupd/dmn011
2	Oviduct: Roles in fertilization and early embryo development	230	Li and Winuthayanon	Journal of Endocrinology	2017	Review	10.1530/JOE-16-0302
3	The role of essential trace elements in embryonic and fetal development in livestock	205	Hostetler <i>et al.</i>	Veterinary Journal	2003	Review	10.1016/S10900233(02)00310-6
4	The role of oxidative stress and antioxidant balance in pregnancy	185	Hussain <i>et al.</i>	Mediators of Inflammation	2021	Review	10.1155/2021/9962860
5	The role of antioxidant enzymes in the ovaries	166	Wang <i>et al.</i>	Oxidative Medicine and Cellular Longevity	2017	Review	10.1155/2017/4371714

Source: Data obtained from Scopus (2026).

Table 2. Journals with the greatest contribution in research regarding the use of selenium and/or vitamin E in reproduction (2000-2025).

Journals	Documents	Quartile	Category	IF	Journal country
Tropical Animal Health and Production	5	Q2	Animal agriculture	1.7	United Kingdom
Animal Feed Science and Technology	3	Q1	Animal feed	2.7	The Netherlands
Zygote	3	Q4	Early embryology	1.4	United Kingdom
Antioxidants	3	Q1	Science & technology	6.6	Switzerland
Biological Trace Element Research	3	Q1	Medical applications	3.6	United States
International Journal of Molecular Sciences	3	Q1	Biochemistry, Molecular Biology, Multidisciplinary	4.9	Switzerland
Reproduction in Domestic Animals	3	Q2	Animal Science and Zoology	1.7	Germany
Veterinary Sciences	3	Q1	Animal health & vet. medicine	2.3	Switzerland
Animal Reproduction Science	2	Q1	Reproduction & fertility in animals.	3.3	The Netherlands
Abanico Veterinario	2	Q4	Animal sciences	0.4	Mexico

Source: Data obtained from Scopus (2026).

The 192 publications on the effect of selenium and/or vitamin E on reproduction and those related to oxidative stress in the period from 2000 to 2025 were published by 52 countries. The top 10 participating countries are shown in Table 3; they have contributed 131 publications (68%) of the total publications, with Turkey (11.97%) and China (11.45%) leading the list. It is worth noting that the top five countries account for a cumulative percentage of 46.3% of total publications, representing almost half of the scientific corpus and highlighting the strong leadership of these nations in this area of research. Interestingly, in the top-10, we can find countries from Asia (5),

America (3), Africa (1), and Oceania (1). Of the three countries in the Americas, two belong to Latin America, where Brazil (9 publications) and Mexico (8 publications) stand out, demonstrating their great interest and productivity in Se and/or Vit E supplementation in animal reproduction.

Table 3. Top ten most productive countries in publications related to reproductive use of selenium and/or vitamin E (2000-2025).

Rank	Country	Publication number and (%)	Cumulative percentage (%)
1	Turkey	23 (11.97)	11.97
2	China	22 (11.45)	23.42
3	India	17 (8.85)	32.27
4	United States	15 (7.81)	40.08
5	Pakistan	12 (6.25)	46.33
6	Brazil	9 (4.68)	51.01
7	Australia	9 (4.68)	55.69
8	Mexico	8 (4.16)	59.85
9	Egypt	8 (4.16)	64.01
10	Iran	8 (4.16)	68.17

Source: Data obtained from Scopus, Science Direct & Google Scholar (2026).

The authors with the highest productivity were identified based on the number of published documents and Total Link Strength (TLS), i.e., the strength or intensity of the connections between authors, related to the topic of selenium and/or vitamin E supplementation in ruminant reproduction (Table 4). Each author's scientific impact was determined based on the number of citations and the H-index reported in the corpus obtained from the Scopus platform.

Table 4. Top five most influential authors based on total link strength (TLS) on selenium and/or vitamin E supplementation and its impact on reproduction from 2000 to 2025.

Rank	Author	Articles	TLS	Citations	H-index	Affiliation	Country
1	Cui, L.	2	15	983	18	Yangzhou University	China
2	Zhang, Z.	2	14	4797	42	Northeast Agricultural University	China
3	Kumar, A.	2	11	389	11	ICAR - Indian Institute of Agricultural Biotechnology	India
4	Aichler, M.	2	9	14189	45	Helmholtz Zentrum Munchen - German Research Center for Environmental Health	Germany
5	Quesnel, H.	2	9	3406	33	L'Institut Agro Rennes-Angers	France

Source: Data obtained from Scopus (2026).

Figure 4(a) shows the number of author distribution clusters formed after being visualized with VOSviewer with a threshold of 1 document per author. There are 184 clusters and 741 authors, some of which had no direct connection; the software has the option of showing the group with the largest number of connected authors, in our specific case, 15 authors, according to what was observed in the second part of Figure 4. The color gradient from purple to yellow indicates the progress in publications from previous years to the most current, in our case, from 2010 to 2025.

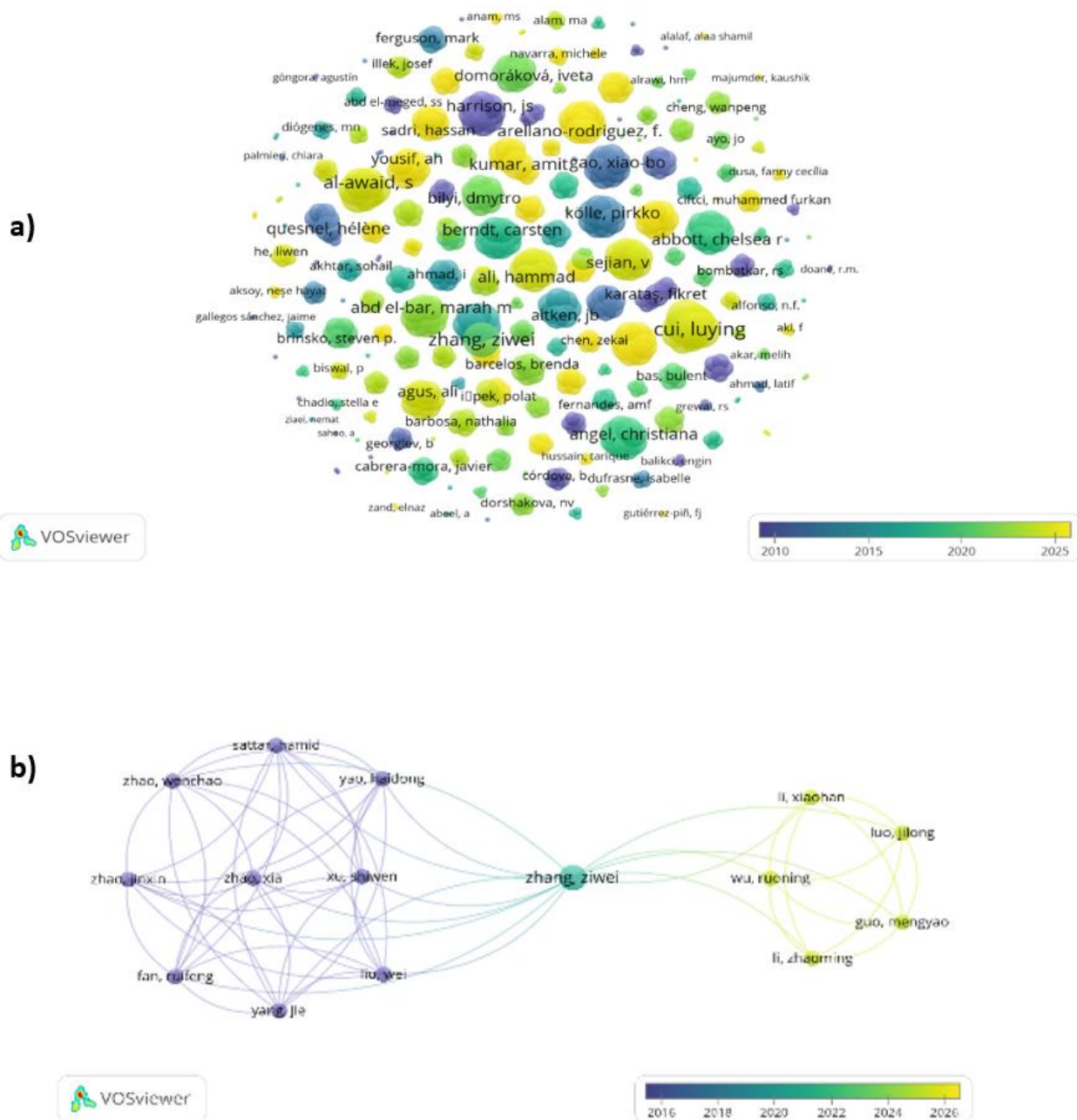
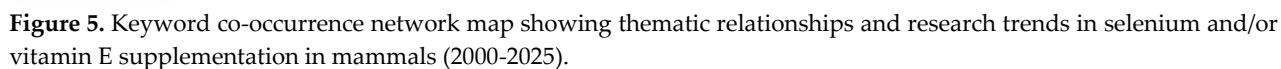


Figure 4. Visualization maps of collaboration networks among the main authors in research on selenium and/or vitamin E supplementation in mammals (2000-2025) (a) General co-authorship network; (b) largest connected cluster; colors (purple-yellow) indicate the progression of the year of publication, node size reflects productivity, and link thickness indicates the strength of the collaboration.

Figure 5 shows the keywords used in the topic of scientific research on the effect of selenium and/or vitamin E on reproduction and those related to oxidative stress; it shows four groups formed after being visualized with the VOSviewer software. Some of the most frequent keywords are female, animal, pregnancy, physiology, livestock, oxidative stress, antioxidants, selenium, metabolism, supplementation, embryonic development, veterinary medicine, among others.



Scientometric and bibliometric approaches have become valuable tools for assessing scientific productivity and research trends. Their evolution, driven by the expansion of large databases and analytical platforms, has facilitated the identification of knowledge gaps and research disparities, providing a framework to evaluate whether specific topics or animal species remain underrepresented in the scientific literature (Macías-Chapula 2001, Okubo 1997, Lyu *et al.* 2023). This study hypothesized that scientific research on the use of antioxidant supplements such as selenium and/or vitamin E in reproduction, specifically regarding ovulation and implantation rates, is limited in goats compared to other animal species. Furthermore, it was expected that the main contributors to this area of research would be highly developed countries, particularly those facing recurrent heat stress that affects animal production. Our results partially support this hypothesis. Research explicitly focused on goats was scarce, while most publications addressed other ruminant species or broader mammalian models. Nevertheless, these studies were included because goats are biologically classified as both ruminants and mammals, allowing for the incorporation of potentially relevant evidence for caprine reproductive physiology. The overall publication pattern offers insight into the evolution of scientific interest in antioxidant supplementation for reproduction; however, scientific output was concentrated primarily in

developing countries, particularly in Asia. This distribution may reflect the growing interest in antioxidant-based nutritional strategies not only to improve reproductive performance but also to mitigate the adverse effects of climate change-related stress factors on animal production systems. Our results allow us to understand publication trends over a period of just over more than two decades, from 2000 to 2025. In this scientometric analysis, a peak in the number of publications was observed from 2010 onwards, with the highest number of publications in 2025, with 39 documents; it is expected that such growth will continue further.

Research related to selenium and/or vitamin E supplementation highlights a growing trend in reproduction in both humans and animals in recent times (Majors *et al.* 2025, Aslan 2025, Mojadadi *et al.* 2021). The initial period of research yielded low publication rates, likely because prior studies had focused on other topics, such as the toxicological role of selenium (Wilber 1980, Shamberger 1983), rather than on its potential role as an essential trace element for reproduction. The scientometric patterns here identified suggest a progressive diversification of research topics over time, including studies addressing antioxidant functions and their association with reproductive and immune processes. Another factor that can be inferred is the sustained growth of goat research studies; yet, although dairy goat production has increased since the 1970s, it was not until 2010 that production skyrocketed globally (Meza-Herrera *et al.* 2024). This possibly explains the increase in research related to supplements and especially antioxidants that improve both production and reproduction in this animal species.

Diverse authors, countries, and journals have been actively present in publications. In fact, the most cited article is the one entitled "Oxidative stress and antioxidants: Exposure and impact on female fertility", published in 2008 in the journal Human Reproduction Update with 290 citations (Ruder *et al.* 2008), this highlights its visibility and influence in scientific research on topics related to the use selenium and vitamin E as antioxidants, and how both molecules influence the maintenance of pregnancy. Among the journals with the highest global influence, Tropical Animal Health and Production is the one that publishes the most research articles (5), where articles focused on the nutritional effects of selenium and vitamin E on reproductive parameters such as fertility, birth rates (Farahavar *et al.* 2020, Awawdek *et al.* 2019, Ataman *et al.* 2023), progesterone levels (Farahavar *et al.* 2020), metabolic status (Barcelos *et al.* 2022) and effects of climate change on oxidative stress in the health, production and reproduction (Rathod *et al.* 2025), with goats and sheep stand out. The following 3 articles published in Animal Feed Science and Technology are highlighted for the effect of complementary supplementation with alternative feeds with antioxidants such as selenium and vitamin E (Blache *et al.* 2008) as well as their direct administration during the reproductive period in ruminants to determine fertility rates, ovulation, embryo development and effects on puberty in ruminants (Robinson *et al.* 2006, Surai and Fisinin 2015). The third journal, Zygote (3 publications), emphasizes antioxidant supplementation, one of them insulin-transferrin-selenium (ITS) (Guimarães *et al.* 2016, Lin *et al.* 2024), on *in vitro* embryo production (Zarbakhsh 2021). These articles support the research approaches of these journals on improving livestock productivity, health, and management through nutrition and breeding.

All these publications were generated by different countries. From the 10 countries with the most frequent contributions, Turkey leads with 23 publications, followed by China (22) and India (17); all from Asia. Besides, the results also highlight the geographical distribution of scientific

publications on antioxidant supplementation with a focus on animal reproduction. Other studies emphasize the importance of small ruminant farming in Turkey, a developing country, due to its geographical and sociocultural conditions, but with an old tradition of animal production of economic importance under arid and semi-arid ecotypes (Hanoğlu and Yildiz 2025, Aydin *et al.* 2024). Although this analysis was not designed to identify implicit factors related to the leadership of specific countries, this view certainly provides complementary information for interpreting the observed distribution of scientific output.

Regarding co-authorship maps, the network analysis provides insight into collaboration patterns among researchers within a specific research area or “knowledge hub” (Martínez-Toro *et al.* 2019) and allows us to understand who writes in the same network, either directly or indirectly (University Library 2026), showing the relationship between two cited documents. Our analysis depicted many small author networks with concurrent citations. Such a scenario suggests a fragmentation regarding the scientific interaction among research groups. Therefore, the lack of interaction and the decreased formation of research networks limit the advancement of scientific knowledge. In contrast, interdisciplinary and cooperative research accelerates discoveries in reproductive physiology (Martínez-Toro *et al.* 2019).

The growth dynamics of scientific production varied according to the biological model used. Of the 192 documents included in the analysis, only a small proportion focused explicitly on goats ($n = 14$), while a larger number of studies specifically addressed cattle ($n = 33$) and sheep ($n = 47$). The remaining publications referred more generally to categories such as “ruminants” or “mammals,” without distinguishing individual species. The last allowed the analysis to consider potentially relevant findings related to physiological, reproductive, and nutritional processes. In this regard, Fraire-Cordero *et al.* (2013) and Özar *et al.* (2022) argue that, although there is interest in the topic of selenium and/or vitamin E supplementation, the participation of goats is marginal. Such a trend justifies an increased effort to augment research in this species. Undoubtedly, more in-depth studies are required, especially on follicle development, oocyte and sperm maturation, fertilization, embryo development, and implantation, as well as studies at different physiological stages. The last must allow understanding of the mechanisms involved, elucidating and providing theoretical support for how this mineral acts together with other supplements (Dahlen *et al.* 2022, Wu *et al.* 2025). This research topic is likely to continue to grow, as oxidative stress related to climate change, including changes in temperatures and the low availability of quality food, is a central topic of relevance to livestock production around the world (Rathod *et al.* 2025). Further research on nutrigenomics and epigenetic mechanisms that regulate the metabolic pathways of offspring from the maternal diet with antioxidants in the periconceptional period is specifically needed (Craner *et al.* 2025).

CONCLUSIONS

This scientometric analysis shows the evolution of publications on selenium and vitamin E supplementation in animal reproduction from 2000 to 2025, reflecting the increasing recognition of antioxidant strategies as key factors influencing reproductive performance and physiology. Despite the growing and recent volume of literature, most research has focused predominantly on

livestock species other than goats, revealing a limited understanding of the specific effects of these antioxidants on the caprine species. The analysis identifies important knowledge gaps that can guide future research, as well as strengthen interdisciplinary and international research networks. Future studies should prioritize research focused on goats, as well as emerging areas such as nutrigenomics, maternal-fetal programming, epigenetic regulation, oxidative stress pathways, and the long-term effects of antioxidant supplementation during critical reproductive stages.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ADDITIONAL INFORMATION

The datasets used in this research are available from the corresponding author upon reasonable request.

LITERATURE CITED

- Arbeláez GM, Onrubia GJ (2014) Análisis bibliométrico y de contenido. Dos metodologías complementarias para el análisis de la revista colombiana Educación y Cultura. *Revista de Investigaciones UCM* 14(23): 14-31.
- Aslan FA (2025) The role of antioxidants in enhancing reproductive performance in sheep: Physiological, molecular, and applied perspectives. *Black Sea Journal of Agriculture* 8(6): 875-884. <https://doi.org/10.47115/bsagriculture.1746955>
- Ataman MB, Aköz M, Dönmez N, Bodu M, Kul M, Bucak MN (2023) The investigation of the effects of vitamin A, vitamin E, and β -carotene plus vitamin E on some fertility parameters in ewes. *Tropical Animal Health and Production* 55(3): 175. <https://doi.org/10.1007/s11250-023-03586-4>

- Awawdek Sra, Eljarah AH, Ababneh MM (2019) Multiple injections of vitamin E and selenium improved the reproductive performance of estrus-synchronized Awassi ewes. *Tropical Animal Health and Production* 51(6): 1421-1426 <https://doi.org/10.1007/s11250-019-01826-0>
- Aydin KB, Bi Y, Brito LF, Ulutaş Z, Morota G (2024) Review of sheep breeding and genetic research in Türkiye. *Frontiers in Genetics* 15: 1308113. <https://doi.org/10.3389/fgene.2024.1308113>
- Barcelos B, Gomes V, Vidal AMC, de Freitas Júnior JE, de Araújo MLGML, Alba HDR, Netto AS (2022). Effect of selenium and vitamin E supplementation on the metabolic status of dairy goats and respective goat kids in the peripartum period. *Tropical Animal Health and Production* 54(1): 36. <https://doi.org/10.1007/s11250-021-03034-1>
- Blache D, Maloney SK, Revell DK (2008) Use and limitations of alternative feed resources to sustain and improve reproductive performance in sheep and goats. *Animal Feed Science and Technology* 147(1): 140-157. <https://doi.org/10.1016/j.anifeedsci.2007.09.014>
- Cardona-Román DM, Sánchez-Torres JM (2017) Análisis cuantitativo de la producción científica acerca de la investigación sobre la evaluación de la implementación del e-learning en el periodo 2000-2015. *Educación* 26(51). <https://doi.org/10.18800/educacion.201702.001>
- Craner AJ, Dahlen CR, Hurlbert JL, Menezes ACB, Banerjee P, Baumgaertner F, Bochantin-Winders KA, Amat S, Sedivec KK, Swanson KC, Diniz WJS (2025) Maternal vitamin and mineral supplementation affected neonatal gene expression and rewired key regulatory genes underlying hepatic metabolism. *Animals* 15: 2664. <https://doi.org/10.3390/ani15182664>
- Dahlen CR, Reynolds LP, Caton JS (2022) Selenium supplementation and pregnancy outcomes. *Frontiers in Nutrition* 9: 1011850. <https://doi.org/10.3389/fnut.2022.1011850>
- Daramola JO, Abioja MO, Iyaser OS, Oke OE, Majekodunm BC, Logunleko MO, Adekunle EO, Nwose EU, Smith OF, James IJ, Williams TJ, Abiona JA (2021) The resilience of Dwarf goats to environmental stress: A review. *Small Ruminant Research* 205: 106534. <https://doi.org/10.1016/j.smallrumres.2021.106534>
- Davis TC, White RR (2020) Breeding animals to feed people: The many roles of animal reproduction in ensuring global food security. *Theriogenology* 150: 27-33. <https://doi.org/10.1016/j.theriogenology.2020.01.041>
- Farahavar UN, Rostami Z, Alipour D, Ahmadi UN (2020) The effect of pre-breeding vitamin E and selenium injection on reproductive performance, antioxidant status, and progesterone concentration in estrus-synchronized Mehraban ewes. *Tropical Animal Health and Production* 52(4): 1779-1786. <https://doi.org/10.1007/s11250-019-02183-8>
- Fraire-Cordero S, Pró-Martínez A, Ramírez-Valverde G, Sánchez-del Real C, Gallegos-Sánchez J (2013) Selenio y vitamina E en la fertilidad de ovejas Pelibuey sincronizadas con progesterona. *Universidad y Ciencia* 29(1): 33-44.
- Gonzalez-Bulnes A, Meza-Herrera CA, Rekik M, Ben Salem H, Kridli RT (2011) Limiting factors and strategies for improving reproductive outputs of small ruminants reared in semi-arid environments. In: Degenovine KM (ed). *Semi-arid environments: Agriculture, water supply, and vegetation*. Nova Science Publishers Inc, Hauppauge, NY, USA. pp. 41-60
- Guimarães AL, Pereira SA, Diógenes MN, Dode MA (2016) Effect of insulin-transferrin-selenium (ITS) and l-ascorbic acid (AA) during *in vitro* maturation on *in vitro* bovine embryo development. *Zygote* 24(6): 890-899. <https://doi.org/10.1017/s0967199416000228>
- Hanoğlu OH, Yildiz F (2025) Structural characteristics of small ruminant production in muş, Türkiye: A model for organic livestock on the basis of sustainability. *Sustainability* 17(7): 3019. <https://doi.org/10.3390/su17073019>

- Hernández-García JM, Castellanos-Potenciano BP, Ramírez-Guillermo MA, Ramos-Hernández E (2024) Análisis bibliométrico sobre la producción científica de *Maconellicoccus hirsutus* (1971-2021). *Revista Mexicana de Ciencias Agrícolas* 15(8). <https://doi.org/10.29312/remexca.v15i8.3071>
- Hostetler CE, Kincaid RL, Mirando MA (2003) The role of essential trace elements in embryonic and fetal development in livestock. *Veterinary Journal* 166(2): 125-139. [https://doi.org/10.1016/s1090-0233\(02\)00310-6](https://doi.org/10.1016/s1090-0233(02)00310-6)
- Hussain T, Murtaza G, Metwally E, Kalhoro DH, Kalhoro MS, Rahu BA, Sahito RGA, Yin Y, Yang H, Chughtai MI, Tan B (2021) The role of oxidative stress and antioxidant balance in pregnancy. *Mediators of Inflammation* 2021: 9962860. <https://doi.org/10.1155/2021/9962860>
- Kaya S, Koçak G, Demir MC, Kaçar C (2023) The effect of vitamin E- trace mineral treatments on reproductive performance in Morkaraman sheep during the breeding season. *Kafkas Universitesi Veteriner Fakultesi Dergisi* 29(2): 161-169. <https://doi.org/10.9775/kvfd.2022.28901>
- Li S, Winuthayanon W (2017) Oviduct: Roles in fertilization and early embryo development. *Journal of Endocrinology* 232(1). <https://doi.org/10.1530/joe-16-0302>
- Lin J, Ji Z, Zeng S (2024) Insulin-transferrin-selenium supplementation improves porcine embryo production *in vitro*. *Zygote* 32(6): 452-458. <https://doi.org/10.1017/s0967199424000200>
- Lu CD (2023) The role of goats in the world: Society, science, and sustainability. *Small Ruminant Research* 227: 107056. <https://doi.org/10.1016/j.smallrumres.2023.107056>
- Lyu P, Liu X, Yao T (2023) A bibliometric analysis of literature on bibliometrics in recent half-century. *Journal of Information Science* 52(2): 324-344. <https://doi.org/10.1177/01655515231191233>
- Macías-Chapula CA (2001) Papel de la informetría y de la cienciometría y su perspectiva nacional e internacional. *Acimed* 9(2): 1-10.
- Majors C, Myers A, Kasimanickam R (2025) Selenium in cattle diseases and reproductive health. *Clinical Theriogenology* 17: 12015. <http://dx.doi.org/10.58292/CT.v17.12015>
- Martínez-Toro GM, Rico-Bautista D, Romero-Riaño E, Galeano-Barrera CJ, Guerrero CD, Parra-Valencia JA (2019) Análisis de la estructura intelectual y la evolución de la investigación en la interacción humano-computador: Un análisis bibliométrico. *Iberian Journal of Information Systems and Technologies* 17: 363-378.
- Meza-Herrera CA, Gonzalez-Bulnes A, Kridli RT, Mellado M, Arechiga-Flores CF, Salinas H, Luginbuhl JM (2010) Neuroendocrine, metabolic and genomic cues signalling the onset of puberty in females. *Reproduction in Domestic Animals* 45(6): e495-e502. <https://doi.org/10.1111/j.1439-0531.2009.01355.x>
- Meza-Herrera CA, Navarrete-Molina C, Luna-García LA, Perez-Marin C, Altamirano-Cárdenas JR, Macias-Cruz U, García de la Peña C, Abad-Zavaleta J (2022) Small ruminants and sustainability in Latin America & the Caribbean: Regionalization, main production systems, and a combined productive, socio-economic & ecological footprint quantification. *Small Ruminant Research* 211(6): 106676. <https://doi.org/10.1016/j.smallrumres.2022.106676>
- Meza-Herrera CA, Navarrete-Molina C, Macias-Cruz U, Arellano-Rodriguez G, De Santiago-Miramontes A, Sariñana-Navarrete MA, Marin-Tinoco RI, Perez-Marin CC (2024) Dairy goat production systems: A comprehensive analysis to reframe their global diversity. *Animals* 14: 3717. <https://doi.org/10.3390/ani14243717>
- Meza-Herrera CA, Tena-Sempere M (2012) Interface between nutrition and reproduction: The very basis of production. In: Astiz S, Gonzalez-Bulnes A (eds) *Animal Reproduction in Livestock*. Encyclopedia of Life Support Systems (EOLSS), under the auspices of the UNESCO, EOLSS-UNESCO Publishers, Oxford, UK. <http://www.eolss.net/outlinecomponents/Reproduction-in-Livestock.aspx>. Data consulted: 15 march, 2026.
- Meza-Herrera CA, Vicente-Pérez A, Osorio-Marín Y, Girón-Gómez BS, Beltrán-Calderón E, Avendaño-Reyes L, Correa-Caldeón A, Macías-Cruz U (2015) Heat stress, divergent nutrition level and late pregnancy

- in hair sheep: Effects upon cotyledon development and litter weight at birth. *Tropical Animal Health & Production* 47(05): 819-824. <https://doi.org/10.1007/s11250-015-0794-7>
- Michán L, Muñoz-Velazco I (2013) Cienciometría para las ciencias médicas: Definiciones, aplicaciones y perspectivas. *Investigación en Educación Médica* 2(6): 100-106. [http://dx.doi.org/10.1016/S2007-5057\(13\)72694-2](http://dx.doi.org/10.1016/S2007-5057(13)72694-2)
- Mojadadi A, Au A, Salah W, Witting P, Ahmad G (2021) Role for selenium in metabolic homeostasis and human reproduction. *Nutrients* 13: 3256. <https://doi.org/10.3390/nu13093256>
- Mora AS de los A, Zeledón AAS, Vargas RT (2019) Estrés oxidativo y antioxidantes: Efectos en el embarazo. *Revista Médica Sinergia* 4(5): 89-100. <https://doi.org/10.31434/rms.v4i5.211>
- Navarrete-Molina C, Meza-Herrera CA, De Santiago-Miramontes A, Valenzuela-Núñez LM, Marin-Tinoco RI, Soto-Cardenas MA, Sariñana-Navarrete MA (2024) Dairy goat production: Socioeconomic, environmental, and cultural importance across time (1970–2022) and possible scenarios (2050). *Resources* 13: 177. <https://doi.org/10.3390/resources13120177>
- Navarrete-Molina C, Meza-Herrera CA, Herrera-Machuca MA, Macias-Cruz U, Veliz-Deras FG (2020) Not all ruminants were created equal: Environmental and socio-economic sustainability of goats under a marginal-extensive production system. *Journal of Cleaner Production* 255: 120237. <https://doi.org/10.1016/j.jclepro.2020.120237>
- Okubo Y (1997) Bibliometric indicators an analysis of research systems: Methods and Examples. OECD Science, Technology and Industry working paper. Paris, France. 8p. <https://doi.org/10.1787/208277770603>
- Özar E, Sarıbay MK, Köse AM, Sertkol R (2022) Effects of selenium, vitamin E, and β -carotene administration on fertility of Awassi ewes synchronized for estrus in non-breeding season. *Veterinary Journal of Mehmet Akif Ersoy University* 7(3): 167-174. <http://doi.org/10.24880/maeuvsf.1117948>
- Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, Alonso-Fernández S (2021) Declaración PRISMA 2020: Una guía actualizada para la publicación de revisiones sistemáticas. *Revista Española de Cardiología* 74(9): 790–799. <https://doi.org/10.1016/j.recesp.2021.06.016>
- Pieczynska J, Płaczkowska S, Sozański R, Grajeta H (2024) Is maternal selenium status associated with pregnancy outcomes in physiological and complicated pregnancy?. *Nutrients* 16(17): 2873. <https://doi.org/10.3390/nu16172873>
- Rakha SI, Elmetwally MA, Ali H, Balboula A, Mahmoud AM, Zaabel SM (2022) Importance of antioxidant supplementation during *In Vitro* maturation of mammalian oocytes. *Veterinary Sciences* 9(8): 439. <https://doi.org/10.3390/vetsci9080439>
- Rathod AK, Somagond YMEL, Kumar A, K KK, Nikhil KC, Jadhav SE, Aderao GN (2025) Role of micronutrients in production and reproduction of farm animals under climate change scenario. *Tropical Animal Health and Production* 57(2): 31. <https://doi.org/10.1007/s11250-025-04283-0>
- Robinson JJ, Ashworth CJ, Rooke JA, Mitchell LM, McEvoy TG (2006) Nutrition and fertility in ruminant livestock. *Animal Feed Science and Technology* 126: 259-276. <https://doi.org/10.1016/j.anifeedsci.2005.08.006>
- Romero VDM, Camarena GBO (2023) El consumo sustentable y responsable: conceptos y análisis desde el comportamiento del consumidor. *Revista Vértice Universitario* 25(94). <https://doi.org/10.36792/rvu.v25i94.75>
- Ruder EH, Hartman TJ, Blumberg J, Goldman MB (2008) Oxidative stress and antioxidants: Exposure and impact on female fertility. *Human Reproduction Update* 14(4): 345-57. <https://doi.org/10.1093/humupd/dmn011>

- Sa'ayinzat FE, Bawa EK, Ogwu D, Ayo JO (2021) Oxidative stress and its effects on reproductive performance in thermally-stressed ewes. *International Journal of Veterinary Sciences and Animal Husbandry* 6(4): 09-17. <https://doi.org/10.22271/veterinary.2021.v6.i4a.361>
- Santos-Silva R, Meza-Herrera CA, Castro-Roque B, Calderón-Leyva G, Navarrete-Molina C, Ángel-García O, Flores-Salas JM, De Santiago-Miramontes A, Arellano-Rodríguez F, Rosales-Nieto CA (2025) Selenium + Vitamin E supplementation in anestrus goats: A strategy to enhance reproductive outcomes under a semi-arid production system. *Animals* 15(10): 1421. <https://doi.org/10.3390/ani15101421>
- Shamberger RJ (1983) Toxicity of selenium. In: Springer, Boston, Massachusetts (eds) *Biochemistry of selenium. Biochemistry of the Elements*, Springer Nature. https://doi.org/10.1007/978-1-4684-4313-4_7
- Surai PF, Fisinin VI (2015) Selenium in sow nutrition. *Animal Feed Science and Technology* 211(2016): 18-30. <https://doi.org/10.1016/j.anifeedsci.2015.11.006>
- University Library (2026) Bibliometric analysis and visualization. <https://researchguides.uic.edu/bibliometrics/vosviewer>. Data consulted: 08 march, 2026.
- Urrutia-Morales J, Meza-Herrera CA, Escobar-Medina FJ, Gamez-Vazquez HG, Ramirez-Andrade BM, Diaz-Gomez MO, Gonzalez-Bulnes A (2009) Relative roles of photoperiodic and nutritional cues in modulating ovarian activity in goats. *Reproductive Biology* 9(3): 283-294. [https://doi.org/10.1016/s1642-431x\(12\)60032-1](https://doi.org/10.1016/s1642-431x(12)60032-1)
- Wang S, He G, Chen M, Zuo T, Xu W, Liu X (2017) The Role of Antioxidant Enzymes in the Ovaries. *Oxidative Medicine and Cellular Longevity* 2017: 4371714. <https://doi.org/10.1155/2017/4371714>
- Wilber CG (1980) Toxicology of Selenio: A review. *Clinical toxicology* 17(2): 171-230.
- Wodajo HD, Gameda BA, Kinati W, Mulem AA, van Eerdewijk A, Wieland B (2020) Contribution of small ruminants to food security for Ethiopian smallholder farmers. *Small Ruminant Research* 184: 106064. <https://doi.org/10.1016/j.smallrumres.2020.106064>
- Wu R, Li X, Li Z, Luo J, Zhang Z, Guo M (2025) Selenium and mammalian uterine health: A comprehensive review. *Biology* 14: 1295. <https://doi.org/10.3390/biology14091295>
- Zarbakhsh S (2021) Effect of antioxidants on preimplantation embryo development *in vitro*: a review. *Zygote* 29(3): 179-193. <https://doi.org/10.1017/s0967199420000660>