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Bibliometric Global Research Trends on Snail Farming

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Abstract: Snail farming (Heliciculture) has been recognized as a vital agricultural sector in many parts of the world because of its role in the production of animal protein. However, less research has been carried out on the holistic picture of the global research status on snail studies. We aimed to make a bibliometric evaluation based on a total of 212 research articles on snail research published between 1949 and 2023 using Rstudio software. Studies on snail research were positively correlated with the number of years ($R^2 = 0.474$; $y = 0.1162x–228.03$) suggesting that this field is receiving global attention. The most productive nation in terms of publication and citation numbers was the USA, while the organization with the most publications was Kyushu University in Japan. "Snail/s" was the keyword of the most relevant subject, Journal of Molluscan Studies was the principal scholarly source and A, Staikou and Neiman M were the most impactful authors in snail research. Production, reproduction, growth, biodiesel, gastropod, and food security were the foremost keyword hotspots in this field. These findings can assist scientists and other stakeholders in better comprehending the directions of snail research, which are valuable for future investigations and agricultural practice in the field.

Keywords: Bibliometrics, Gastropods, Helicicuture, Rstudio, Visualization Analysis

Introduction

Snails are a high-value food resource in human diets and a source of exceptional byproducts (e.g. caviar, mucus, bioactive compounds) with immense commercial worth (Bonnemain, 2005; Agbugba *et al*., 2023). In the dermatological industry, the use of snail extract has increased because it exhibits therapeutic, sedative, as well as anti-aging characteristics (Tsoutsos *et al*., 2009). Globally snails are referred to as a vital protein source for supplying the ever-growing global population, which is projected to reach nine billion human beings by the year 2050 (Apostolou *et al*., 2021). Snail consumption at the global level is well over 400,000 tons yearly (Aromolaran *et al*., 2019). Reports on the consumption of edible snails by most countries in Europe alone surpasses 100,000 tons, with an aggregate import of the animal reaching a 49 % increase between 1995 and 2010 (Virgiliu, 2012). The largest snail meat consumption is reported in Spain, Portugal, France, and Morocco (Rygało-Galewska *et al*., 2022). Several countries including Morocco played a vital role in the producer market of snail meat in 2020 with a percentage of world export of 15.6 (Rygało-Galewska *et al*., 2022). Other countries such as Lithuania (8.6%) and Romania (7.5 %) are among the world exporters (Rygało-Galewska *et al*., 2022). Meanwhile, some countries with the largest import of snails include France (25.3% of world imports), Spain (21.6%) as well as Romania (8.5%), respectively (Rygało-Galewska *et al*., 2022). In the country of Greece alone, snail farming constitutes an alternative source of income generation (Hatziioannou *et al*., 2014). Likewise in developing nations, snail farming serves as a means of finance generation for people (Okwuokenye *et al*., 2023). Snails are also served as ready-to-eat meat in many cultures in developing nations (Afolabi, 2013). A few years ago, the Food and Agriculture Organization (FAO) raised an alarm about animal protein deficiency in the diets of so many people in developing countries (Agbugba *et al*., 2023). The reason for this is partly due to the high cost of conventional sources of animal protein such as beef, chicken, mutton, pork, and chevon which most people cannot afford (Owolade and Kayode, 2012). This situation has shifted the attention of people to look for other alternative sources of animal protein to meet the daily per capita animal protein intake of the minimum requirement of 35 g as recommended by FAO as against the less than l0 g eaten by a lot of people in developing nations (Agbugba *et al*., 2023). The protein content in snail meat is richer (37-51%) as compared to chicken

(18.3%), beef (17.5%), fish (18%), mutton (16.4%) and pork (14.5%) (Agbugba *et al*., 2023). Furthermore, research has shown that snail meat contains other vital nutrients such as calcium, amino acids, iron (45-59 mg/kg), and moderately low-fat content (0.05-0.08%) required for maintaining good human health (Vivian *et al*., 2016). Furthermore, snails have been used in the treatment of some human ailments such as hypertension, anemia, and other fat-related sicknesses (Owolade and Kayode, 2012). Owing to the high-quality protein content, snail meat has attracted high demand in many cuisines and is drawing considerable attention worldwide. With the increased demand for snail meat globally, the beneficial significance of snail farming cannot be over-emphasized because of its great prospects in the sector. Other advantages of snail farming include the low capital requirement to set up, less expertise, very high fecundity and low mortality rate, less labor intensive, no noise pollution, easy to handle, the small space requirement for breeding, easily adapt to different environmental conditions and available in the market for sales (Baba and Adeleke, 2006; Agbogidi *et al*., 2008). Snail farming is a fascinating development opportunity for families and small and medium-scale farmers due to the fact that they are easy to breed. They also do not require large financial sums to start their production. They require little human labor during the production cycle when compared to other livestock farming. They need moderately little land space for maintenance, both in the field as well as indoors (Rygało-Galewska *et al*., 2022). A very important aspect of snail farming is that, they emit little greenhouse gases or other harmful gases into the environment and are stress-free to integrate into an organic system of farming (Zucaro *et al*., 2016).

Regardless of the handful of investigations on snail farming in scholarly pieces of literature, to date, it appears that publications documenting the number of papers in this research domain are very sparse compared to the economic importance and environmental significance of snails and hence, the present investigation becomes of essence. The technique of employing bibliometrics for evaluating research studies is a unique instrument for the logical representation and characterization of research findings in a particular scholarly field. This approach pools together mathematical permutations and statistical computations to project the academic knowledge that has the possibility of forecasting research direction in a particular research discourse (Zou *et al*., 2019; Idamokoro, 2023). Bibliometrics thus, simplifies roadmaps for academics, institutions, and policymakers to put together strategies, proposals, and policies that will advance important investigations with technological innovations that are capable of improving research within the niche area (Olisah and Adams, 2020). Evaluation of literature using a bibliometric approach is a vital field of research that helps to weigh the magnitude of global scholarly growth in a given research field (Zhang *et al*., 2019). Concerning the previously mentioned reasons, the current study, utilized a bibliometric method to report the trends as well as research publications associated with snail farming using data collected from two Vita data banks, Scopus and Web of Science (WOS) from 1949-2023.

Therefore the study aims to pinpoint and present worldwide research scope on snail farming studies, for instance, authors, keywords, distributions of countries, research outputs, the global trends of citations, and topic hotspots on the present subject of interest.

Materials and Methods

Management and Analysis of Data

The current study used two data sources (Scopus and WOS) to collect documents on snail farming research. These two databases are known sources often used for investigations of this type of study because they have wide coverage of data capture and search questions for bibliometric evaluation (Zhang *et al*., 2023). These data banks from WOS (http://www.webofknowledge.com) and Scopus (http://www.scopus.com) are globally accepted sources because of their reliability for credible articles (Repiso *et al*., 2018). The title search was employed to gather data documents from Scopus and WoS for a wider collection of documents required for the study from 1949-2023. Data were then cleaned up and filtered before they were authenticated for assessment. The process of data cleaning was achieved by browsing literature to get appropriate author keywords that align with the proposed subject matter. Our method of data collection has previously been used by another author (Fesseha *et al*., 2020). All retrieved and cleaned documents were transferred into the R Studio package to take out all duplicated articles from the combination of WOS and Scopus documents. An illustration of the data collection, inclusion, and exclusion is given in Fig. (1).

Data Processing

After the collection of data from WOS and SCOPUS, they were analyzed using the bibliophily function before they were evaluated for their descriptive visualization in the bibliometric R-Studio software package. The descriptive bibliometric R-Studio was used to obtain the following results; global publication distribution per year, number of citations by different authors and nations, journal source and their global impact, and the trends of associated topics amongst others as described by Aria and Cuccurullo (2017). The RStudio software package was also used to describe other bibliometric results which include author's keywords/ contributions; article keywords/ keywords plus; author global influence; institutions; frequency of citations, word cloud, etc. The international impact of authors' influence within the snail farming research niche is assessed by Lotka's law (Lotka, 1926).

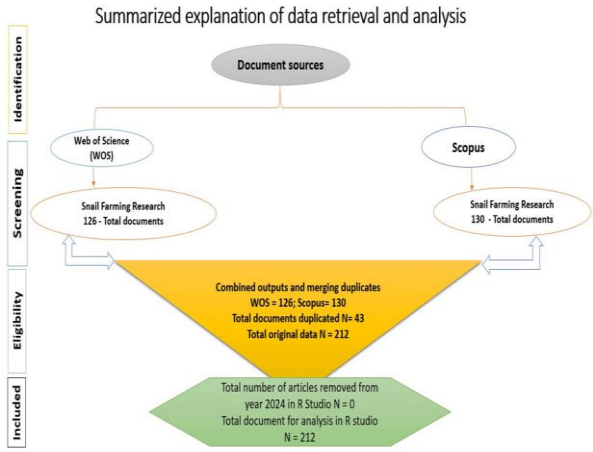

Fig. 1: Summary of inclusion and exclusion of articles on snail farming for bibliometric analysis

Results and Discussion

Information of the Research Summary on Snail Farming

The main information of all articles collected from WOS and SCOPUS is given in Table (1). The number of articles that fall within the subject area between 1949 and 2023 was 212 and is available in 145 data archives from 617 scholarly authors. The single-authored publications were written by 20 authors, whereas the co-authors per documents on snail farming had a percentage of 3.77 authors, accordingly. There was a sum of 4716 references with a document average age of 17.30. In addition, the average number of citations per document in snail farming was 19.10. The result of the author keywords (DE) and keyword plus (ID) was 504 and 1285, respectively. All the aforementioned information (Table 1) gives a bibliometric summary of the literature breakdown of a research niche as reported in other associated bibliometric fields (Idamokoro and Niba, 2024).

Literature Types Analyzed for the Present Study

The snail farming research field comprises eight types of documents (Fig. 2), with research articles being the most predominant type of publication, accounting for 92% of the whole type in the snail farming literature. This shows that articles are the principal means of scholarly communication in this research field. Conference papers, proceeding papers, and book chapters were also significant avenues of academic communication, representing 6, 3 and 3% of the total literature, respectively. Similar findings have also been reported for bibliometric analysis of the document types (Ekundayo and Okoh, 2018; Sharma and Sisodia, 2021).

Table 1: Articles retrieved on snail farming research from WoS and Scopus archive

Description	Results
Main information about the data	
Timespan	1949:2023
Sources (Journals, Books, etc)	145
Documents	212
Annual Growth Rate %	2.81
Document average age	17.3
Average citations per doc	19.1
References	4716
Document contents	
Keywords Plus (ID)	1285
Author's Keywords (DE)	504
Authors	
Authors	617
Authors of single-authored docs	20
Authors collaboration	
Single-authored docs	28
Co-Authors per Doc	3.77
International co-authorships %	9.434

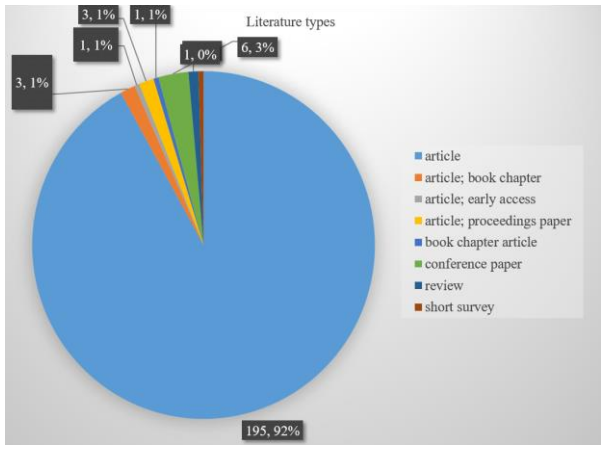

Fig. 2: Literature types of the snail farming publications from WoS and Scopus from 1949-2023

Annual Increase in Articles and Citation Numbers on Snail Farming Research

The bibliometric study is a scholarly tool commonly used to define the increase of an academic topic in a research niche over the years concerning the annual articles published within that year. For example, a yearly reduction in the number of articles produced in a particular field of research indicates a decreasing interest by academics and scientists in that research issue (Okaiyeto and Oguntibeju, 2021). Concerning research work on snail farming research, not many publications were observed in the early years (1949-2009) as seen in Fig. (3). Meanwhile, from 2010 there was a considerable increase in research on snail farming to date (Fig. 3). The highest number of articles

on snail farming research was recorded in 2023, with 20 research articles. In addition, research performance in this field recorded an annual rise of 2.81%. Meanwhile, this finding of annual growth rate was lower as compared to other bibliometric studies (Orimoloye and Ololade, 2021; Idamokoro and Hosu, 2022a-b). The rise in research publications on snail farming from the year 2010 and going forward is indicative that there is a growing global interest in the subject matter particularly concerning nutrition and food security. This may be because aside from their ability to produce high-value food products, they are also an important source of exceptional by-products (mucus, caviar, and bioactive compounds) with great commercial worth (Apostolou *et al*., 2021). In agreement with the present findings, a related study on 'apple snails' reported an increasing trend in publication numbers over the years (Yao *et al*., 2023). Some publications on this subject matter also require more time to gain a global satisfactory readership before they can earn more citations. Snail farming plays an essential role as a source of business in reducing poverty in some parts of the world, especially in developing countries (Agbugba *et al*., 2023) and as an economic tool capable of reducing multi-dimensional poverty (Apostolou *et al*., 2021).

The increase in snail farming is also linked to the fact that they are a delicacy certified as a conventional food product in several countries of the globe (Apostolou *et al*., 2021; Agbugba *et al*., 2023). The meat and eggs from snails don't only taste very good, but, they have large amounts of digestible vitamins, protein, and minerals that are beneficial for the body system (Virgiliu, 2012). Snails further serve as raw products for the production of different medicinal products, which contribute to the activation of essential processes as well as body rejuvenation (Virgiliu, 2012).

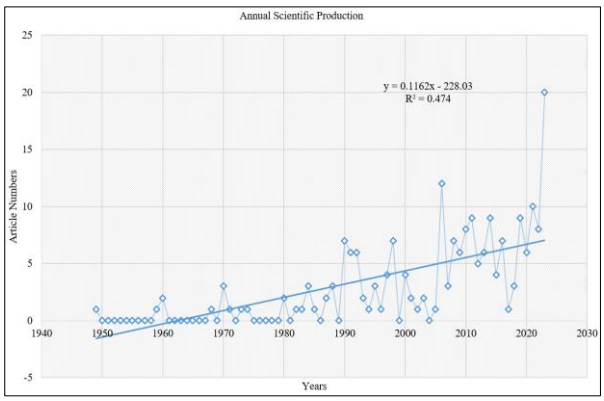

Fig. 3: Annual article numbers on snail farming research from 1949-2023

Global Influential Researchers on Snail Farming Research

From the current study, it was shown that 617 authors participated in the writing of 212 articles from 1949-2023. In addition, the co-authors per publication was 3.77 and the proportion of international co-authorship was 9.43%, which indicates the level of networking and partnership by various local and international scholars in the research field. Table (2) shows the 25 most impactful authors in this research niche, with the highest h-index of 7 and the highest article citations of 167. The number of citations observed in the study was anticipated because of the relatively low number of authors who reported their findings on snail farming. This result was in line as compared to other bibliometric results which had a lesser number of citations as a result of fewer authors involved in research in their field (Tywabi-Ngeva *et al*., 2022; Amira *et al*., 2022). Meanwhile, with regards to the h-index score, is a yardstick that is often employed to evaluate the impact of any author within a given research niche (Huang *et al*., 2019). The h-index scores are used to assess how significant the research (through the amount of article citations) of any author is been viewed in the global community (Hirsch, 2005). The global score of authors, nations, institutions, and journal outlets are determined from their h-index assessment which often aligns with the number of academic articles and citations from other researchers. H_index analysis is determined by using the logic which states that h research articles were cited for h number of times over a given time (Hirsch, 2005). The h-index index that is used for the assessment of an author's relevance or global performance is a very vital tool that gives accurate replicates of the intellectual impact to the pool of existing knowledge by an author (Guilak and Jacobs, 2011).

Meanwhile, it has been argued that using only article numbers as a metric for rating a paper does not give the exact impact of an author in a particular niche of research because the rating did not take into account the number of co-authors involved in writing the said paper (Altarturi *et al*., 2023). An efficient benchmark has however been suggested for rating an author's (or co-author's) performance, which is by using a fractionized metric to rate every article that is published under a niche area. This kind of evaluation is achieved by dividing the score of a published paper among the co-authors who contributed to the work if the paper is not a sole author publication (Altarturi *et al*., 2023). This approach of evaluating author impact gives each author or co-author (of a specific paper) a score of 1 divided by the number of contributing authors of the manuscript (Chriki *et al*., 2020).

The result observed from Table (2), indicated how the 25 most relevant authors performed, from where authors such as Staikou A, Neiman M, Baur B,

Lazaridoudimitriadou M, and Rondelaud D contributed 8, 6, 5, 5, and 8 articles from the total aggregate of 212 documents from WoS and Scopus, accordingly. Furthermore, the aforementioned authors had an h-index of 7, 6, 5, 5, and 5, respectively. However, the author named Kim, Y (h-index = 4) in the 8th position had a higher citation (n = 158) when compared to authors (from second to seventh-ranked) in the field. This indicates the fact that the use of article citations does not only impact an author's rating, other factors like the year of publication also do (Okaiyeto and Oguntibeju, 2021). In contrast with the result of the present study, Yao *et al*. (2023) reported different authors as the most impactful researchers on investigations carried out for apple snail (invasive snail-types) research.

The Global Impactful Institution on Snail Farming Research from 1949-2023

The information for the top twenty-four (24) institutions with the highest amount of publications in snail farming is given in Table (3). The Kyushu University of Japan (n = 14), the Marmara University of Turkey (n = 7), and the Northwest University of China (n = 7) had the highest amount of articles on snail farming globally, accordingly among others. This finding of the present result is in contrast with previous bibliometric studies that have always reported institutions from the USA as top-ranked institutions from a wide spread of research from different disciplines (Chriki *et al*., 2020; Idamokoro and Niba, 2024). In line with our findings, Yao *et al*. (2023) reported institutions from the USA and Asia as some of the top-rated institutions doing research in snail farming. Only two institutions from Africa namely Sidi Mohamed Ben Abdellah University from Morocco and the University of Nigeria from Nigeria were listed among the most influential institutions in the present study. Although Africa is known to do a lot of research in snail farming (Chah and Inegbedion, 2013; Agbugba *et al*., 2023), their low number of representations may be a result of the fact that most of their publications do not feature globally indexed databases such as PubMed, Google Scholar, Scopus and WOS among others. Another possible reason may be that people do not report work on snail farming from those regions as a result of financial constraints. Financial challenges and limitations have deprived several developing nations of the ability to report research findings on a global stage (Ekundayo and Okoh, 2018).

Table 2: Top 25 impactful authors in snail farming research from 1949- 2023

S/N	Author name	h_index	g_index	m_index	TC	NP	PY_start
1	Staikou A	7	8	0.189	167	8	1988
2	Neiman M	6	6	0.316	124	6	2006
3	Baur B	5	5	0.152	111	5	1992
4	Lazaridoudimitriadou M	5	5	0.143	71	5	1990
5	Rondelaud D	5	8	0.185	90	8	1998
6	Civitello D	4	4	0.667	40	4	2019
7	Dreyfuss G	4	7	0.148	80	7	1998
8	Kim Y	4	4	0.267	158	4	2010
9	Vignoles P	4	5	0.211	40	5	2006
10	Dudgeon D	3	3	0.200	70	3	2010
11	Maldonado A	3	4	0.176	23	6	2008
12	Nakaji K	3	4	0.176	23	7	2008
13	Oktar F	3	3	0.231	44	3	2012
14	Abrous M	2	2	0.074	48	2	1998
15	Agathopoulos S	2	2	0.154	41	2	2012
16	Alonso-Del-Rivero M	2	2	0.333	10	2	2019
17	Artacho P	2	2	0.125	21	2	2009
18	Baker G	2	3	0.059	48	3	1991
19	Barlough J	2	2	0.074	76	2	1998
20	Baur A	2	2	0.061	53	2	1992
21	Bellet V	2	2	0.105	23	2	2006
22	Bert V	2	2	0.400	27	2	2020
23	Blanc J	2	2	0.0800	36	2	2000
24	Bonnet J	2	2	0.080	36	2	2000
25	Bosnia A	2	2	0.057	47	2	1990

Most Influential Journal Source on Snail Farming Research

There are several journal sources for manuscript publication and these sources suggest the research specialty and scope of these journals. The number of topics in a known journal is a vital standard for determining the impact of the journal in bibliometric study (Leydesdorff and Rafols, 2009). Table (4) shows the most relevant sources (journals) for articles on snail farming. The first five (5) top-ranked journal sources were the Journal of Molluscan Studies (N = 7), Journal of The Faculty of Agriculture Kyushu University (N = 6), Journal of Helminthology (N = 5), Heliyon (N = 4) and Hydrobiologia (N = 4), respectively. These publication sources are recognized for disseminating scholarly findings that are related partly or fully to snail farming research and other associated studies. In line with the present findings, Yao *et al*. (2023) also reported Journal of Molluscan Studies, Hdrobiologia, Malacologia, and Biological Invasions among others as journal sources that are known to be relevant outlets for snail farming research.

Most Impactful Globally Cited Articles on Snail Farming Research

The metrics for rating a research manuscript show the number of citations it accumulates from other authors within a given time. The global citation of research papers is dependent on the value of the citing paper rather than how famous the paper is being cited in the academic sphere. For instance, a scholarly document that is cited by a very impactful manuscript often attracts global attention from other researchers who are experts in the field, whereas the amount of citations of a paper draws its global influence without taking into account the value of the manuscripts that are citing it. The Total Citation (TC), as well as total citation per year (TC/Year) in Table (5), ranged from 42-176 and from 1.02-26.80. The impact of a paper in a research field is often assessed by the number of citations (Tahim *et al*., 2016). This citation power increases with years as the citation number increases (Faggion *et al*., 2017). The increase in citation numbers of a paper may draw negative criticism as a result of self-citations done by some authors on their articles (Cheek *et al*., 2006). Howbeit newly published manuscripts may have fewer citations at the initial stage but, their citations grow with years of publication (Feijoo *et al*., 2014).

The top-ranked cited documents in snail farming research from 1949-2023 are shown in Table (5). Authors such as Halwart M (1994), Laskar IB (2018), Silliman BR (2003), Hall RO (2006), and Krishnamurthy KN (2020) published the five (5) globally most cited documents on snail farming with each paper having over 150 citations. All these aforementioned articles were published in the International Journal of Pest Management (TC: 176; TC/Year: 5.68), Royal Society of Chemistry Advances (TC: 169; TC/Year: 24.14), Proceedings of the National Academy of Sciences of the United States of America (TC: 169; TC/Year: 7.68), Ecological Application (TC: 165; TC/Year: 8. 68) and Renewable Energy (TC: 134; TC/Year: 26.80), accordingly.

Table 3: The top 24 global relevant research institutions on snail farming research

S/N	Affiliation	Nations	Articles	Position
1	Kyushu Univ	Japan	14	1st
2	Marmara University	Turkey	7	2nd
3	Northwest Univ	China	7	2nd
4	Aristotle Univ Thessaloniki	Greece	6	3rd
5	Univ Florida	USA	6	3rd
6	Univ Naples Federico Ii	Italy	6	3rd
7	Vytautas Magnus Univ	Lithuania	6	3rd
8	Emory Univ	USA	5	4th
9	Free University	Germany	5	4th
10	Kyoto Sangyo Univ	Japan	5	4th
11	Natl Inst Technol Silchar	India	5	4th
12	Univ Basel	Switzerland	5	4th
13	Univ Buea	Cameroun	5	4th
14	Andong Natl Univ	South Korea	4	5th
15	Indiana Univ	USA	4	5th
16	Jinan Univ	China	4	5th
17	Sidi Mohamed Ben Abdellah Univ	Morocco	4	5th
18	Univ Autonoma Barcelona	Spain	4	5th
19	Univ Nigeria	Nigeria	4	5th
20	Univ Thessaloniki	Greece	4	5th
21	Univ Thessaly	Greece	4	5th
22	Univ Vigo	Spain	4	5th
23	University of Thessaloniki	Greece	4	5th
24	Warsaw Univ Life Sci	Poland	4	5th

Table 4: Top 25 journals in terms of publications on snail farming research from 1949-2023

S/N	Sources	Articles	Percentage (%)
1	Journal of Molluscan Studies	7	3.30
2	Journal of the Faculty of Agriculture Kyushu University	6	2.83
3	Journal of Helminthology	5	2.35
4	Heliyon	4	1.88
5	Hydrobiologia	4	1.88
6	Australian Journal of Zoology	3	1.41
7	Invertebrate Biology	3	1.41
8	Invertebrate Reproduction and Development	3	1.41
9	Invertebrate Reproduction \& Development	3	1.41
10	Journal of Parasitology	3	1.41
11	Key Engineering Materials	3	1.41
12	Malacologia	3	1.41
13	Renewable Energy	3	1.41
14	RSC Advances	3	1.41
15	Animals	2	0.94
16	Archives of Environmental Contamination and Toxicology	2	0.94
17	Biologia	2	0.94
18	Biological Invasions	2	0.94
19	Biological Journal of the Linnean Society	2	0.94
20	Biology of the Cell	2	0.94
21	Comparative Biochemistry and Physiology -- Part B: Biochemistry and	2	0.94
22	Ecology	2	0.94
23	Ekologia Polska	2	0.94
24	Environmental Science and Pollution Research	2	0.94
25	Estudios De Cultura Maya	2	0.94

Table 5: Top 25 most cited documents in snail farming research

S/N	First author and Journal name	DOI	Total Citations	TC per Year	Normalized TC
1	Halwart M, 1994, Int J Pest Manage	10.1080/09670879409371882	176	5.68	1.00
2	Laskar IB, 2018, Rsc Adv	10.1039/c8ra02397b	169	24.14	2.76
3	Silliman BR, 2003, Proc Natl Acad Sci Usa	10.1073/pnas.2535227100	169	7.68	1.90
4	Hall RO, 2006, Ecol Appl	10.1890/1051-0761(2006)016[1121:EHSPOI]2.0.CO;2	165	8.68	4.20
5	Krishnamurthy KN, 2020, Renew Energy	10.1016/j.renene.2019.06.161	134	26.80	2.67
6	Krishnamurthy KN, 2020, Renew Energy	10.1016/j.renene.2019.06.161	117	23.40	2.33
7	Roschat W, 2016, Bioresour Technol	10.1016/j.biortech.2016.03.038	88	9.78	2.55
8	Mason CF, 1970, Oecologia	10.1007/BF00344885	87	1.58	2.90
9	Chanmee T, 2014, J Biol Chem	10.1074/jbc.M114.564120	75	6.82	2.59
10	Oppliger A, 1998, Proc R Soc B-Biol Sci	10.1098/rspb.1998.0468	74	2.74	2.38
11	Kaewdaeng S, 2017, Energy Procedia	10.1016/j.egypro.2017.10.057	70	8.75	1.00
12	Wright B, 2006, Biol Cell	10.1042/BC20050066	67	3.53	1.71
13	Dolara A, 2016, Ieee J Photovolt	10.1109/JPHOTOV.2016.2576682	66	7.33	1.91
14	Becker S, 2008, Appl Microbiol Biotechnol	10.1007/s00253-008-1385-6	66	3.88	4.40
15	Okumura N, 2015, Lab Invest	10.1038/labinvest.2015.111	65	6.50	2.86
16	Wright B, 2006, Biol Cell	10.1042/BC20050066	61	3.21	1.55
17	Gupta P, 2014, Mol Oncol	10.1016/j.molonc.2014.06.006	56	5.09	1.93
18	Kwong KL, 2010, Biol Invasions	10.1007/s10530-009-9537-x	56	3.73	2.36
19	Gupta P, 2014, Mol Oncol	10.1016/j.molonc.2014.06.006	55	5.00	1.90
20	Dikkeboom R, 1988, Dev Comp Immunol	10.1016/0145-305X(88)90068-7	55	1.49	1.27
21	Staikou A, 1988, J Molluscan Stud	10.1093/mollus/54.2.139	53	1.43	1.22
22	Huryn AD, 1995, J N Am Benthol Soc	10.2307/1467538	46	1.53	2.23
23	Pflüger W, 1980, Z Parasitenkd	10.1007/BF00927532	46	1.02	1.96
24	Liu H, 2016, Renew Energy	10.1016/j.renene.2016.03.017	45	5.00	1.30
25	Reubel GH, 1998, J Clin Microbiol	10.1128/jcm.36.6.1501-1511.1998	42	1.56	1.35

Top Influential Countries Based on the Number of Publications and Citations in Snail Farming Research

The top 24 influential countries with the most articles and citations on snail farming research are shown in Table (6). Eleven (11) countries are from Europe (France, Greece, Spain, Switzerland Italy, Poland, Turkey, UK, Denmark, Germany, and Lithuania), five (5) countries are from Asia (i.e. China, Japan, Thailand, India, and Korea), two (2) countries from Africa (Nigeria and Cameroun), three (3) of the countries are from North America (i.e. USA, Mexico, and Canada) and three (3) countries are from South America (Argentina, Brazil, and Chile), accordingly. This result clearly shows that European countries were more intentional in their research on snail farming. The article contributions from the USA, China, France, Greece, and Nigeria depict them as real influential countries in the research field. In line with the present result, Japan, India, Brazil, the USA, China, and Chile were reported among countries well-known for doing research in snail farming (Yao *et al*., 2023). Based on the World Bank report, the result showed that most of the studies on snail farming were from financially stable nations, followed by nations from upper to middle-income class countries (World Bank, 2024). A relatively few studies were carried out in lower to middle-income class countries (Table 6).

There were position switches and exchanges among the top 24 most influential countries in snail farming when the outcomes were evaluated based on Total Citation (TC) per country (Table 6). This observation is in line with the results of other bibliometric studies (Orimoloye and Ololade, 2021; Idamokoro and Niba, 2024). The reason for the ranking switch when using the citation numbers to assess the author's publications may describe its unpredictability as a reliable yardstick to define the productivity of researchers in bibliometric studies. Fricke *et al*. (2013) reported that the frequency of article citations in a particular country does not tell the number of publications of an author or nation. The reason is that the lesser the number of articles used in bibliometric analysis, the more significant a few regularly cited articles (Fricke *et al*., 2013). Some writers are involved in self-citations, while others give false citation references when citing other authors' work and this leads to pseudo-qualitative and quantitative standards of citations of nations or authors.

Table 6: Topmost relevant countries in snail farming research based on article numbers and citations

Rating based on article numbers							Rating based on TC		
S/N	Country	Articles	SCP	MCP	Freq	MCP_Ratio	Country	TC	Average article citations
1	USA	28	26	2	0.132	0.071	USA	873	31.20
2	China	18	15	3	0.085	0.167	India	431	86.20
3	France	11	10	1	0.052	0.091	Germany	242	121.00
4	Japan	11	9	2	0.052	0.182	China	179	9.90
5	Greece	10	10	0	0.047	0	Thailand	177	29.50
6	Nigeria	8	7	1	0.038	0.125	Japan	175	15.90
7	Spain	6	5	1	0.028	0.167	Switzerland	159	31.80
8	Thailand	6	6	0	0.028	0	Greece	145	14.50
9	India	5	5	0	0.024	0	United Kingdom	143	47.70
10	Switzerland	5	5	0	0.024	0	France	129	11.70
11	Italy	4	3	1	0.019	0.25	Spain	100	16.70
12	Mexico	4	4	0	0.019	0	Italy	92	23.00
13	Poland	4	4	0	0.019	0	Korea	81	27.00
14	Cameroon	3	2	1	0.014	0.333	Denmark	55	27.50
15	Canada	3	2	1	0.014	0.333	Turkey	42	14.00
16	Korea	3	2	1	0.014	0.333	Canada	40	13.30
17	TURKEY	3	3	0	0.014	0	Argentina	28	14.00
18	United Kingdom	3	3	0	0.014	0	Australia	24	24.00
19	Argentina	2	2	0	0.009	0	Nigeria	23	2.90
20	Brazil	2	2	0	0.009	0	Chile	21	10.50
21	Chile	2	2	0	0.009	0	Egypt	21	21.00
22	Denmark	2	0	2	0.009	1	Poland	20	5.00
23	Germany	2	2	0	0.009	0	Sweden	15	15.00
24	Lithuania	2	2	0	0.009	0	Morocco	10	5.00

Commonly Used Authors' Keywords and Word Cloud in Snail Farming Research

Authors' keywords are utilized as metrics to project research topics and hot spots in various research fields (Xu *et al*., 2023). Several journals often require authors to list the keywords of their research work to see if they meet the scope of the journal before any possible review process on the paper. Authors' keywords are again important to other fellow researchers who intend to extract useful information from a manuscript because it assist them to focus on the main areas that are captured by the writer/s of a publication. This practice is often compulsory and it is included below the abstract section of every manuscript (Okaiyeto and Oguntibeju, 2021). Table (7) and Fig. (4) were used to present the author's keywords for research in snail farming from 1949 and 2023.

Among the most often used keywords globally adopted by authors for snail farming research include snail/s (n = 18), Reproduction (n = 9), Growth (n = 8), Production (n = 8), Biodiesel (n = 7), Gastropod (n = 8), Heliciculture (n = 6), Apple snail (n = 5), Secondary production (n = 5), snail shell (n= 5), Biomass (n = 4), Cercarial production (n = 4) and Food security (n = 4) among others. Meanwhile, it is vital to note that most of the previously mentioned keywords from authors have occurrences of n >3 (Table 7). In Fig. (4), the different keyword classifications and sizes with different colors in the word cloud show the strength of the relationship these keywords have to the topic of snail farming. Other earlier studies have also reported the importance of the sizes of keywords on the word cloud chat map and how they are related to specific research domains (Altarturi *et al*., 2023; Idamokoro and Niba, 2024). Meanwhile, our result on keywords was in contrast with the work of Yao *et al.* (2023) who mainly reported invasive snail farming (apple snail). Keywords are used to discuss the themes of vital subjects of a research niche and these keywords also assist would-be authors to pay attention and understand the vital concepts of the niche area (Chen *et al*., 2014).

Table 7: Top most relevant words used by authors in snail farming research

S/N	Words	Occurrences
1	Snail/s	18
2	Reproduction	9
3	Growth	8
4	Production	8
5	Biodiesel	7
6	Gastropod	6
7	Heliciculture	6
8	Apple snail	5
9	Secondary production	5
10	Snail shell	5
11	Biomass	4
12	Cercarial production	4
13	Food security	4
14	Gastropoda	4
15	Helix aspersa	4
16	Invasive species	4
17	Land snail	4
18	Mortality	4
19	Transesterification	4
20	Calcium oxide	3
21	Constraints	3
22	Cornu aspersum	3
23	Density	3
24	Ecology	3

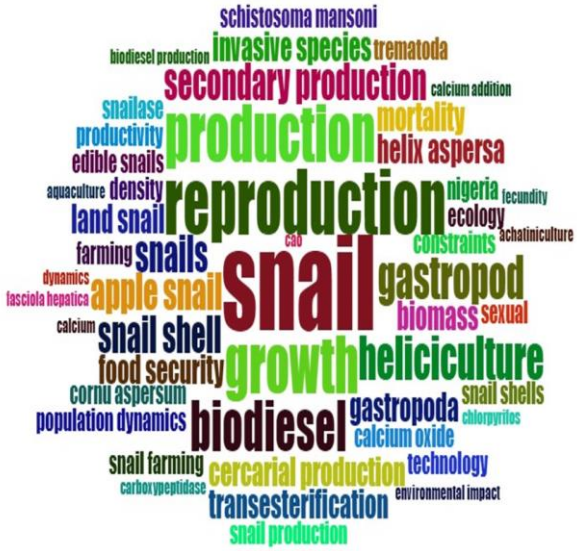

Fig. 4: Word cloud on snail farming research from 1949 to 2023

Treemap of Research Niche Distribution in Snail Farming From 1949-2023

The tree map from Fig. (5) covers a wide range of research distributions which gives a picture of the topic focus within the research niche of snail farming. These field distributions cover areas in taxonomy (e.g. gastropoda, animalia, and mollusca), breeding (e.g. fecundity, size, behavior, optimization, and dynamics), snail characterization and classification (e.g. land snails and pulmonata), adaptations (e.g. temperature and dynamics), food production (e.g. food, soybean oil, and cooking oil), food safety (e.g. apple snail and infection), nutrients (e.g. CaO and calcite), bio-functions (e.g. bioceramics, weeds) and medicinal agent (helix-aspersa) among others. With the research range in snail farming as seen in Fig. (5), it is obvious that the field plays a significant impact in the provision of food (Apostolou *et al*., 2021), means of income generation (Agbugba *et al*., 2023), as a pharmacological agent (Tsoutsos *et al*., 2009; Zhu *et al*., 2024) and nutrient supplier (Owolade and Kayode, 2012) among other functions to the benefits of humans. By harnessing advanced technology and a systematic approach to producing snails on a large scale, they will help to promote sustainable protein meat production and foster economic growth as this venture can turn into an important part of the global food system, especially in developing nations. Conversely, another important benefit of large-scale production of snails is to leverage on snail market as an avenue to provide a rich source of protein meat for people who are unable to afford meat from other livestock including goat, sheep, cattle, and chicken among others.

Fig. 5: Treemap of field distribution in snail farming research

Study Limitation

Despite the global presentation of the bibliometric evaluation (probably the first of its kind) of the present study on snail farming research, it is very essential to also acknowledge some possible limitations that might have emanated from the study. The retrieved articles on snail farming research were obtained from WOS and SCOPUS to allow for a wide coverage of the targeted articles in line with the subject matter. However, there may be possible omissions of some articles that might have been published in other indexed journal archives such as PubMed, Google Scholar, etc, but are omitted in the two databases used for analysis for this study. Therefore, the results from this study may not have covered all the articles on snail farming.

Conclusion

The present bibliometric analysis of research on snail farming shows the global status of snail production and its related field with most of the relevant and influential institutions, countries, and authors from economically stable economies. The study experienced some growth in research on snail farming from the year 2010 to 2023 indicating that research in the niche area is increasing worldwide and it is gaining more attention. This may be because of the need to enhance food production, security, and sustainability. This may be because of the enormous benefits of raising the animal (cheap to set up, eco-friendly, requires small space, nutritious, for biofuels, medicinal, etc.). Researchers from developing nations are encouraged to partner and engage in more research with colleagues from developed nations to help combat the growing challenge of food insecurity and sustainability in those regions. Likewise, due to the growing challenge of food shortage in some developing nations, proper sensitization of people on involving themselves in snail farming for the provision of animal protein and its several nutritious benefits.

Future Directions and Recommendations in Snail Farming Research

The production of snails is a prospective contributor to food security and sustainability worldwide. This aspect of livestock farming gives opportunities to tackle the rising demand for nutritious and healthy food (protein) while also addressing the economic and environmental challenges of several societies, especially developing countries. For example, nations with limited land resources and that are experiencing immense pressure on conventional livestock farming can opt for snail farming to offer a scalable solution for those regions. Likewise, the system of farming snails can be incorporated into circular economic prototypes whereby the use of other agro-waste, by-products, and bio-wastes can be converted as feed for snails to promote resource proficiencies. Efficient breeding programs for enhancing growth rates and decreasing disease resistance could also help to improve the production and sustainability of snail farming. The adoption of advanced technology including automation, sensors as well as data analytics in the future can help to optimize snail production. Furthermore, innovative research on best sustainable production practices such as organic as well as regenerative techniques can guarantee that snail breeding remains eco-friendly in large-scale production.

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Author's Contributions

Emrobowansan Monday Idamokoro: Conceptualized the study, did data collection and analysis, wrote the manuscript, and was involved in manuscript editing.

Augustine Suh Niba: Logistics and supervision. The manuscript was reviewed by the authors.

Ethics

No ethical issues are applicable for this study.

Conflict of Interests

There is conflicting interest.

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